Cost and Structural Optimisation of Modular Bicycle Frame

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***Abstract*— Aim of this study is to outline FE model and finding feasibility of different engineering materials for design of modular bicycle frame. Since conventional fuels are depleting & becoming costlier, in such a case bicycle is good alternative for transport for shorter distances. Bicycle components are cheap and easily available and research is continued since 1800 century and new technologies along with new shapes and cross sections have been evolved. Frame is a main component of bicycle. Accordingly present study we intend to use modular frame which leads to easy assembly and manufacturing of bicycle. Bicycle frame under design consideration intends to fulfill customer needs. The currently available bicycle frame which is having normal standards is not suitable and the frame size and frame height requirements differ from person to person. An attempt is made to overcome this difficulty by using modular frames those are assembled by using welding joints which will help to reduce problems of customer with standard size frames. This paper represents analysis of modular bicycle frame using finite element method. This analysis carried out by applying beam and shell elements with the help of software. This paper also deals with review on welding joints used for assembly of frame. Welding fatigue resistance is dependent on weld geometry & quality but it cannot be assured especially in difficult access joints. The choice of material is mainly structural steel or chrome for this frame. Ashbey's material selection method can be used, that is based on cost per unit properties or multiple properties values. If size of frame is reduced it will give favorable results. Strength to stress ratio of carbon fiber materials depends on fiber direction and stacking sequence. Stiffness is one of the important parameter for bicycle frame, to calculate it standard method was not available. Innovators developed standard multidirectional test method for calculation of stiffness. Analysis of this modular frame has been conducted to compare performance with normal standard size frame. Stiffness, stresses developed and other calculations can be evaluated by considering frame tubes as beam element.**

Keywords–Modular bicycle frame, design, geometry, structural optimization, engineering materials, finite element analysis

I. INTRODUCTION

Modular design, or "modularity in design", is a design approach that subdivides a system into smaller parts called modules or skids that can be independently created and then used in different systems. A modular system can be characterized by functional partitioning into discrete scalable, reusable modules, rigorous use of well-defined modular interfaces, and making use of industry standards for interfaces. Besides reduction in cost due to less customization, and shorter learning time, and flexibility in design, modularity offers other benefits such as augmentation adding new solution by merely plugging in a new module, and exclusion.

Among the human powered vehicles bicycles are the most common and widely used means of transport around the world. There is proof of increasing participation and interest in cycling and lot of literature exists related to bicycle technology. The bicycle frame is the main load bearing structure of the bicycle and in order to select materials for its construction or to make an efficient frame design or the loads carried by the various components must be evaluated under realistic conditions. Frame is crucial component of bicycle hence the material selected should perform satisfyingly under varying conditions of load. Therefore in recent years importance of selection of material has increased. Traditional materials of the bicycle frame are steel or aluminium alloy and using composite material also modular bicycle frame was manufactured. In these frame different forms of composite materials like fiberglass, carbon fiber was used. In this model structural steel going to be use and for high performance chromo material is another choice. Special tools are now available to enhance performance of frame through analysis and iterative improvement. In 1986 steel and aluminium frames were being tested by using finite element method. The aim of this study is to evaluate deflection and stresses developed in modular bicycle frame and comparing it with validated data.

II. LITERATURE SURVEY

James D. Allsopetal explained modular bicycle frame structure using composite material. In this frame he eliminated top tube or a seat post tube. He explained efficient aerodynamic performance of that frame. But for general purpose use structural steel is better to use and He did not explain analysis of frame other than composite frame. Thomas Jin et al. Investigated influence of fibre stacking sequence and orientation on the stress distribution on a carbon epoxy composite frame using shell elements to simulate torsional, frontal and vertical load cases. This study focuses on details

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with the intent of identification and elimination of highly stressed regions. Liu and Wu had not considered stresses developed on each of part.

Joachim et al. found out multidirectional rating test method for bicycle stiffness because measuring method was not standardised and he suggested minor modifications leads to major differences in stiffness values. He explained that when combined loads are applied to frame, It deforms inmultipledirections simultaneously hence making stiffness analysis not straight forward.

Machadol et al. Showed how welded joints play important role foe assembly of bicycle frame. He optimised welding process to ensure better quality and mechanical resistance requirements. He used MIG welding and also realized that welding fatigue resistance dependant on weld geometry and quality and weld quality cannot be assured. In this study he developed such a welding procedure that can be used for large production volume. But he did not focus on modular assemblies and its welding.

Paul Miles et al. Determined experimentally effect of loads on bicycle frame. He did not consider frame as a modular. He tested different loading conditions as static, steady pedaling on smooth, mid-grade, and rough pavement, and hard acceleration on level ground and uphill. The static and hard acceleration cases were directly compared to the FEA model.

III. PROBLEM DEFINITION

Currently available bicycle frames with normal standards are not suitable and the frame size and frame height requirements differ from person to person. An attempt is made to overcome this difficulty by using modular prefabricated frames with welding joints which will help to reduce problems of customer with standard size frames. Steel is the material of choice for manufacturing of modular bicycle frames, with other common materials being aluminium, titanium, chromium and carbon fiber. Steel has a better strength to weight ratio, and a lower cost compared to other materials used for bicycles. Components of specific dimension can be attached to the frame to facilitate the construction of the bicycle of this project so that it is built for a cyclist of specific size.

IV. OBJECTIVES

- To optimize structural rigidity of frame based on selection of material, cross section of frame.
- To validate the FEA methodology using physical frame testing.

V. MATERIAL DESCRIPTION

Various types of materials are feasible for this study. But commonly used material is stainless steel. Hence it is used for FEA analysis. The material used is stainless steel consists of **18%** chromium and 10% nickel and 0.15% carbon added.Material properties are based on cost per unit property and digital logic methods.

Table I MaterialProperties of Composite

Material Name	Young's Modulus (GPa)	Poisson's Ratio
Structural steel	207	0.34

VI. MODELING OF MODULAR BICYCLE FRAME

For this study model is created using CATIA V5 version to represent a road modular bicycle frame including modules or number of different units that mate together to form the whole frame. It includes number of components that are sized to form a frame that is custom shaped for a specific required sized cyclist. Material properties are based on cost per unit property and digital logic methods.

Load cases analysed include vertical load through seat post 2400N (sitting rider) and a simulated scenario of a rider out of the saddle pushing on right pedal. These load cases are based on two extremes as modelled by Maestrelli and Falsini which are based on experimental loads measured by Soden and Adefeye.

Fig.1 Catia Model of modular Bicycle frame Assembly

Figure 1above Shows Catia Model assembly of Modular Bicycle frame. Each load case was analysed on a single frame geometry and then deformation and stresses evolved on each individual part. Modular means to evaluate stresses, deformation such parameters on each part.

TABLE 2MODEL INPUT PARAMETERS OF FRAME

Length in mm	Tube	Tube size (Ø ,Thickness)
500	Top Tube	24.5,1.5
380	Seat Tube	25.4,1.5
620	Down Tube	25.4,2.0
150	Head Tube	33.0,1.5
270	Seat Stays	25.4,1.5
270	Chain Stays	25.4,1.5

VII. FINITE ELEMENT ANALYSIS

Finite element analysis is a technique, which discretizes the model into finite number of elements and nodes. It is actually

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a numerical method employed for the solution of structures or a complex region defining a continuum. This is an alternative to analytical methods that are used for getting exact solution of analysis problems. Finite element analysis involves solving partial differential equations, the primary challenge is to create an equation that approximates the equation to be studied, but is numerically stable, meaning that errors in the input and intermediate calculations do not accumulate and cause the resulting output to be meaningless.

Boundary and Loading Conditions

For finite element analysis this frame is considering as follows. Remote forces of rider and pedalling on right side are considered.

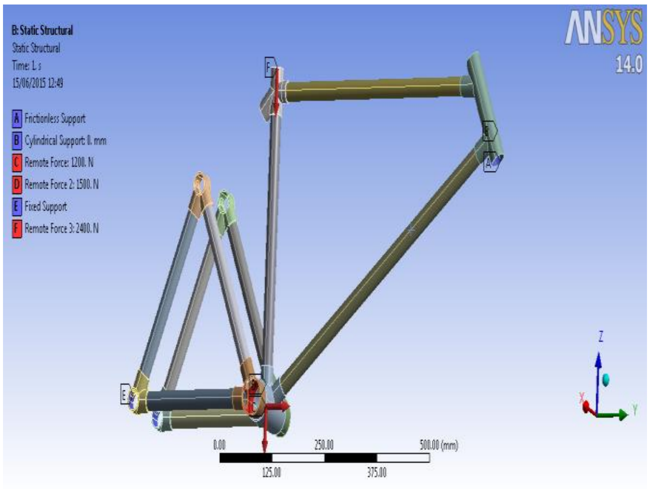

Fig.2 Boundary and loading conditions

VII. Result And Discussions

Fig. 3 shows Deformation plot of frame in vertical load and pedalling on right pedal. From the figure it is concluded that maximum deformation is occurring on seat tube because load applied is 2400 N of maximum value. Since this tube is modular one hence deformation on each of part should be calculated. Here deformation of seat tube is only shown because it gives maximum deformation values.

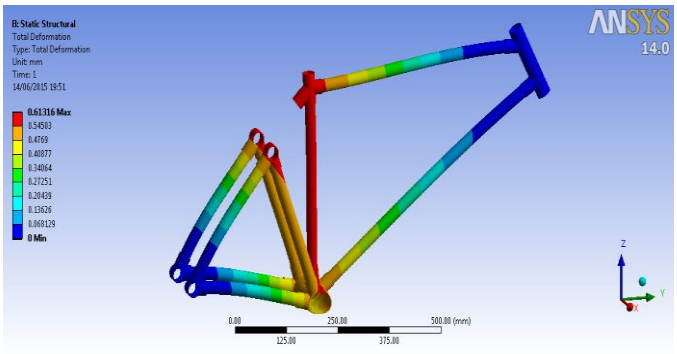

Fig. 3 Total Deformation of modular bicycle frame

Fig. 4 shows deformation of individual seat tube. This figure concludes that if effect of load individually on seat tube is considered then it gives different deformation.

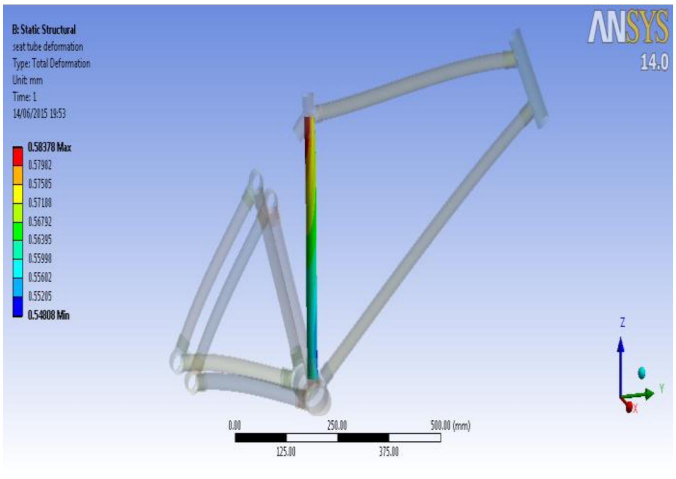

Fig.4 Total deformation of seat tube.

Fig. 5 shows equivalent Von mises stresses produced in assembly stresses are maximum at joints due to change in cross sections and minimum at head tube.

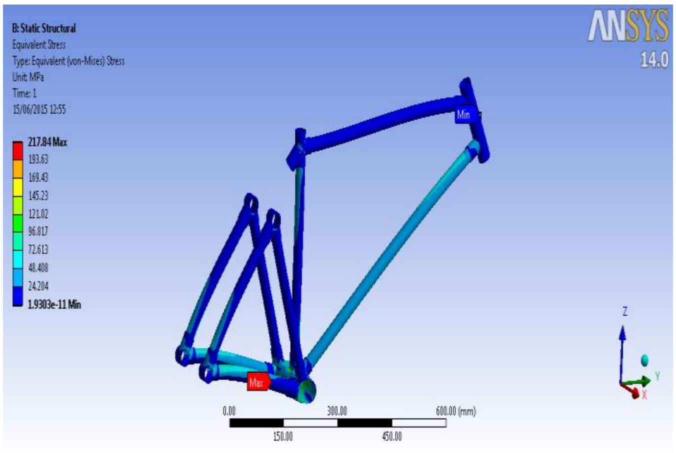

Fig.5 Equivalent Von mises Stresses

VIII. Conclusions

This paper outlines FE model using beam elements to represent standard modular road bicycle frame. The model simulates two standard loading conditions to quantify total deformation and Equivalent von mises stresses. This modular assembly provides better cost and structural optimization. Dimensions changed gives better satisfied results. As per cyclist requirement size of frame can be chosen and assembled.

VII. References

[1] P. Machado1, R.A. Cláudio1, A. Valido, R. Duarte, O. Martins, "pre-validation of welded joints in a bike frame''.

[2]M.A. Maleque and S. Dyuti, "Materials Selection Of A Bicycle Frame Using Cost Per Unit Property And Digital

ISSN: 2278 – 7798

Logic Methods'' , International Journal of Mechanical and Materials Engineering (IJMME), Vol. 5 (2010), No. 1, 95-100.

[3]Derek Covill, "Parametric finite element analysis of bicycle frame geometries", Procedia Engineering 2014 , the conference of the International Sports Engineering Association, University of Brighton, Lewes Rd, Brighton, UK, pp 441-446.

[4] Thomas Jin-Chee Liu , Huang-Chieh Wu, "Fiber direction and stacking sequence design for bicycle frame made of carbon/epoxy composite laminate", Materials and Design 31 (2010) , Ming Chi University of Technology, pp 1971–1980.

[5] Aneliya V. Manolova, Pierre Debraux, William Bertucci, "Strain in BMX frame through different tests", Procedia Engineering 2010, the 8th Conference of the International Sports Engineering Association , France pp 3433.

[6] Joachim Vanwalleghem, Ives De Baere, Mia Loccufier, Wim Van Paepegem, "Development of a multi-directional rating test method for bicycle stiffness", Procedia Engineering 72 (2014), The 2014 conference of the International Sports Engineering Association, Ghent University ,pp 321 – 326.

[7]Nicola Petrone and Federico Giubilato, "Development of a test method for the comparative analysis of bicycle saddle vibration transmissibility", Procedia Engineering 2013 6th Asia-Pacific Congress on Sports Selection, RMIT University Technology & University of Padova, pp 288 – 293.

[8]Paul Miles, Dr. Mark Archibald, "Experimental Determination of Operational Pedal Cycle Frame Loads", Proceedings of the 2012 ASEE North-Central Section Conference.

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