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MODELING AND ANALYSIS OF A BICYCLE FRAME

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Abstract

Design is an important stage in manufacturing. It is because any product produced must be through design stage, where design stage consists of conceptual design, concept selection; identify customer need, concept selection, analysis, and others. In design, many factors should be considered such as product design must be satisfied by customer, material used the ability product to work and others. The main idea in design is to fulfil the customer's need. Besides that, design will have an effect to Company such as profit, loss, and reputation of the company. In this paper have modelled a diamond frame of bicycle by using CATIA v5 and performed finite element analysis on it by using ANSYS18. A conceptual design of bicycle is proposed for reducing the effort kept by cycler while he rides on an inclined plane. The project idea is implementation of four bar mechanism in bicycle.

Keywords: Diamond frame, finite element analysis, four bar mechanism

1. INTRODUCTION

A Bicycle frame should have low weight, high lateral stiffness, and moderate vertical stiffness. Because of chain load, frame lateral deformation during pedaling is bigger when the rider pushes on right pedal (a pro rider may apply a force up to two times his weight). Most of the bicycles built today utilize heat treated steel or aluminum or titanium alloy tubing to minimize their weight. The tubes are then welded together to create the desired fork or frame geometry. It is Notable part in whole racing cycle system which is subjected to static and dynamic loads. Historically, the most common material for the tubes of a bicycle frame has been steel. Steel frames can be very inexpensive carbon steel to highly specialize using high performance alloys. Frames can also be made from aluminum alloys, titanium, carbon fiber, and even bamboo and cardboard. Occasionally, diamond (shaped) frames have been formed from sections other than tubes. These include I-beams and monologue. We will also obtain the knowledge how to make a finite element model in Hyper mesh by going through literature papers. The conditions required for applying various Constraints and how the loads are applied is briefed about in the technical papers referred. By using composite materials, we can reduce the cost of the cycle. Reverse engineer and extract dimension of frame, make a 2D model of Chassis, Designing the chassis using CATIA V5R19. Get the exact parameters of the material used. meshing the CAD model, apply the boundary conditions, solve for the solution of meshed model using ANSYS ’14. re-sequence of the above procedure with new composite material & optimized design and result comparison using the results achieved with two different materials the suitable material is selected. The chassis with composite material is performing better with a satisfying amount of weight reduction. The weight reduction will hence lead to better maneuverability and performance of the vehicle. After analytical and virtual analysis fabrication of the frame will be developed through literature review.

A test base has to be set up in hydro pneumatic press by application of which loads will be provided on loading points and hence forth stress and deformation on the frame will be noted. The validation of the results will be performed by comparing analytical results with technical issued papers. And experimental results will be compares through results achieved through Ansys results. An additional impact test analysis will be validated through LS Dyane Analysis and Technical literatures.The pneumatic tire and the chain drive, followed by the development of gears, revolutionized bicycling in the later 1800s. In the last fifteen years, there has been a revolution of sorts in the development and use of new materials for building frames. It wasn't that long ago that frames were made out of cast iron or even wood. Today bicycles are made out of exotic materials such as titanium, aluminum, and carbon fiber.Bicycle frames in the 1990s are lighter and stronger than ever before. German Inventor Karl von Drais is credited with developing the first bicycle. His machine, known as the "swiftwalker," hit the road in 1817.

This early bicycle had no pedals, and its frame was a wooden beam. The device had two wooden wheels with iron rims and leather-covered tires. As the name suggests, a rider walked on top of the bike with his feet leaving the ground during descents.While it might seem simple and obvious now, getting the rider's feet completely off the ground was a major step (excuse the pun) forward in the development of the bicycle. The velocipedes of the mid 1800s consisted of two wooden tires, a front fork, handlebars for steering, a saddle on wooden frame, and pedals on the axle ofthe front wheel. The velocipede also received a nickname, the "boneshaker." With the rider now completely mounted on the bicycle, he felt all of the bumps--the early velocipedes were not equipped for absorbing vibrations. It wasn't until the development of the pneumatic tire that this problem was effectively addressed. At around the same time the pneumatic tire was developed (1888), lighter materials began to be used for frames, improving the ride dramatically.By the time the modern "safety" bicycle was developed in the late 1800s most frames were made with steel tubing instead of wood or cast iron. While the steel bicycles were quite strong, they were also very heavy. It was not uncommon for a bicycle of that era to weigh in at over 80 pounds (36.28 kg.). Steel frames are still used today, but the tubing has thinner walls and weighs considerably less.

2. PROCESS METHODOLOGY

Material Selection: As per the material survey the best suited material is the aluminum alloy. The mentioned material was chosen as the material for bicycle frame due to its low density and compatible yield strength. This material was chosen for designing frame and comparing its results with different materials as mild steel, EN8 etc. Thus, this paper focuses on optimizing bicycle frame. *Methodology Overview:* After defining the main objectives to investigate fatigue failures, it was determined necessary to obtain a physical bicycle frame to analyze and optimize. Two identical 6061-T6 aluminum prototype mountain bike frames were taken for a fatigue investigation. The investigation not only met the objectives, but also provided value for the local bicycle company by testing and validating the fatigue life of the prototype. An integrated FEA methodology was devised to understand the fatigue behavior of the bicycle frame. The FEA methodology was based on the bicycle specific ASTM F2711-08 test standard. The methodology allowed to use computer simulation to predict the fatigue failure locations of the donated frames, and the cycles to failure in those locations. The FEA methodology was then validated using physical frame testing. A fatigue testing rig was built in-house to test one of the donated frames until failure. The second frame was sent out to an external testing facility to ensure accurate fatigue testing data was obtained. The results between the physical frame testing were compared to the FEA methodology results to determine how well the FEA methodology agreed with actual testing. The analysis was compared and correlated to the observed crack growth rate. A point of origin was found using the SEM to determine exactly where and why the crack originated. After developing the FEA methodology, validating the methodology, and conducting the fractographic analysis, worked towards optimizing the material, heat treatment and geometry design of the frame. Changes were made to each of these characteristics of the frame to work to optimize the fatigue life. Alternative aluminum alloys were investigated as well as alternative heat treatments of 6061 aluminum for the bicycle frame. Finally, modifications to the frame geometry were made to work to improve the fatigue life of the frame. The material, heat treatment and geometry modifications were then combined to result in a bike frame optimized for fatigue resistance.

3. MATERIAL CHOICE

This project involved an investigation into fatigue failures of aluminum mountain bike frames. Two 6061-T6 aluminum mountain bike frames were taken from a local bicycle manufacturer for an investigation into fatigue failure locations and fatigue life. This chapter provides a characterization of the frame tubes of the frames, an overview of the material properties of the frames and a characterization of the process for manufacturing the frames

Optional Material

1. Al-6061-magnesiam and Silicon Major Alloying Element-density 2.70g/Cm^3.
2. Al-7005-Zinc-density-2.78g/cm^3-depending on the temper, may be slightly stronger.

Designing a CAD model required

CAD was developed using 3-D

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modeling software. The cad geometry has basic requirement for Head tube, top tube, bottom tube, chain stays, seat stays, bottom bracket shell and the two triangles commonly says diamond frame. This is the model of the bicycle frame. A bicycle frame is the main component of a bicycle, onto which wheels and other components are fitted. The modern and most common frame design for an upright bicycle is based on the safety bicycle, and consists of two triangles, a main triangle, and a paired rear triangle. This is known as the diamond frame. Frames are required to be strong, stiff and light, which they do by combining different materials and shapes.

Table 1: Comparison of bicycle frames

Material	Density (g/cm3)	Young's Modulus (GPa)	Yield Strength (MPa)
Mild Steel	7.83	210	280-310
Al 6061	2.70	69	64-350
Al 7005	2.78	71	95-345

Table 2: Chemical composition

Chemical Composition	Si	Fe	Cu	M_n	Mg	Cr	Zn	Ti	Al
Al6061	0.62	0.23	0.22	0.03	0.84	0.22	0.10	0.1	Bal
Al7075	0.4	0.5	1.6	0.3	2.5	0.15	5.5	0.2	Bal

Aluminum 6061 compared to other frame materials as seen in the Table 1. Each frame material, including 6061, has advantages and disadvantages when compared to the other materials. The important mechanical properties for comparing bike frame materials include the material's density, tensile strength, fatigue strength, weld ability and cost. Aluminum 6061 has the second lowest density compared to the other materials, with a density that is 60% that of titanium, and 35% of 4130 steel. The tensile strength of 6061 is less than 7005, and around 43% of 4130 steel and titanium. The low density of aluminum allows larger tube diameters to be used to increase frame strength making it to be competitive and even advantageous when compared to steel. The main drawback to titanium, as shown by Table 2, is the tremendously high cost, making the material less common for bicycle frames. Aluminum 6061 is more expensive than steel, but is relatively inexpensive at around $2.43 a kilogram, making it affordable for manufacturing a frame. The main drawback to aluminum is the low fatigue strength compared to the other frame materials.

4. PROBLEM FORMATION AND OBJECTIVES

Frame is the most important part

of a bicycle that holds everything together. To a large extent, the frame affects how aerodynamic and heavy your bike is, how it performs on all types of terrain, how well it handles twists and turns and even how stiff and bumpy the ride on it is. Weight of the bicycle frame plays a major role in determining these factors to conclude whether the bicycle is good or bad. Heavy bicycle frames can make the rider uncomfortable. While climbing steep hills or racing, it would be better to have a lighter frame as it would save the riders efforts and time. Bottom line is that it is essential to choose a bicycle frame which is lighter in weight and strong at the same time especially for mountain/terrain bicycles.

5. OBJECTIVES

- Consider different types of materials.
- Apply different loads.
- Generate the results as per required.
- Evaluate the frame for stress and strain analysis at different loading conditions for Mild Steel, AL6061 and AL7005
- Evaluate the frame for deformation analysis at different loading conditions for Mild Steel, AL6061 and AL7005

6. APPROACH

The following approach can be used for size optimization, shape optimization, topology optimization. Below block diagram shows how we can use these techniques to improve the design and its shape.

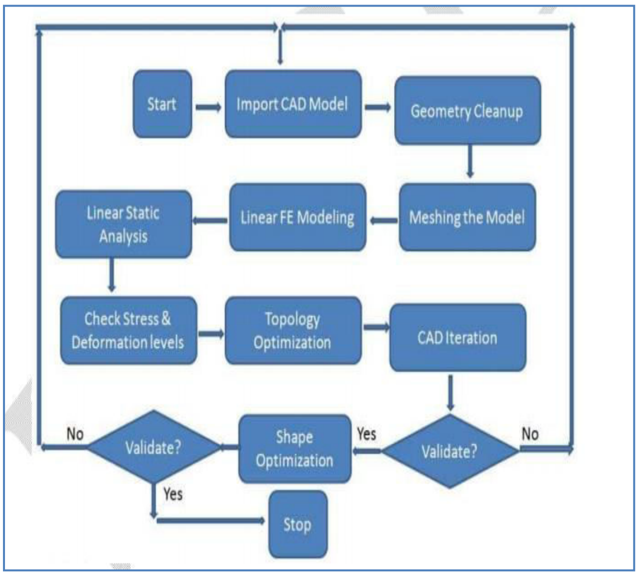

Figure 1 Flow chart showing the Approach

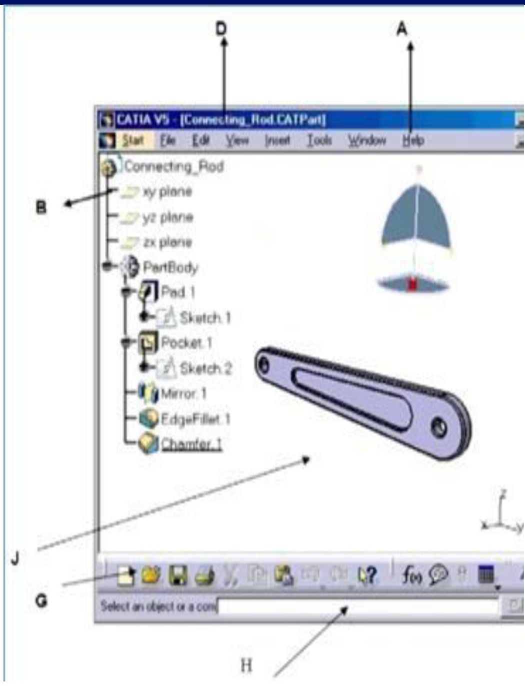

Figure 2: User Interface

Differenttypesofengineeringdrawings,constructionofsolidmodels,assembliesofsolidpartscanbedoneusinginventors.Differenttypesoffilesusedare:

❖ Partfiles:CATPart

❖ Assemblyfiles:CATProduct

7. WORKBENCHES:

Workbenchescontainvarioustoolsthatyoumayneedtoaccessduringyourpartcreation.Youcanswitchbetweenany primary workbenches using thefollowingtwoways:

❖ UsetheStartMenu.

❖ ClickFile>Newtocreateanewdocumentwithaparticularfiletype. Theassociatedworkbenchautomaticallylaunches.

8. PROJECT OBJECTIVES:

After complete of this chapter,

- The basic concept and general working of FEA
- Understand the advantage and limitations of FEA
- Understanding the analysis type
- Understanding important terms and definition of FEA

PLOT CONTOUR OR VECTOR PLOT RESULTS:

Lists the percent error. If you get a message "Cannot view percent error with power graphics on", click the power graphics button on the ANSYS Toolbar to turn it off. List the results for every node. This can be used to get the maximum and minimum values of results.

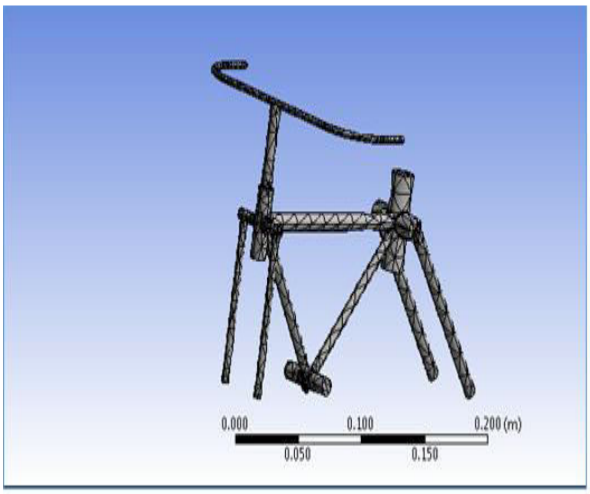

Figure 3: Bicycle Frame Imported to ANSYS

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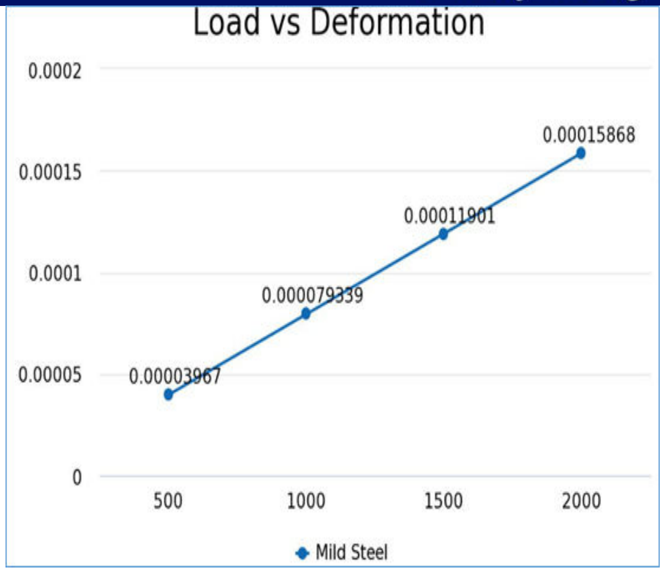
For better quality mesh combination of first and second order tetra elements were used. Surface meshing using triangular elements was performed to achieve better control on the meshing. Further this mesh was converted into a tetra mesh. Selective tetra elements were converted into second order and selective regions were finely meshed using first order elements controlling the number of nodes formed.

Mass	0.56493 kg
Nodes	8142
Elements	4076

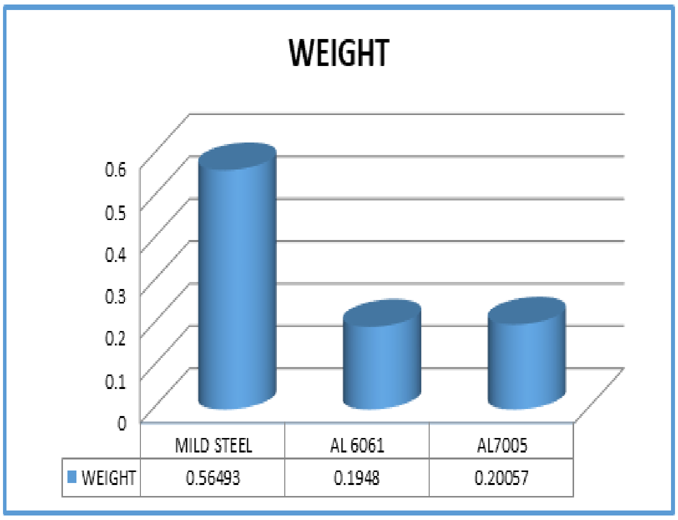
Table 3: Mild steel details

Table 4: Maximum values of load vs Deformation, Strain, Stress of mild steel

LOAD	DEFORMATION	STRAIN	
500	3.967e-5	0.00027644	5.7229e
1000	7.9339e-5	0.00055288	1.1446e
1500	0.00011901	0.00082933	1.7169e
2000	0.00015868	0.0011058	2.2892e



Graph 1: Load vs deformation for mild steel



Graph 2: Weight of materials

9. CONCLUSION

Evaluation of bicycle frame for deformation generated in frame by varying load conditionsEvaluation of bicycle frame for strain generated in frame by varying load conditionsEvaluation of bicycle frame for stress generated in frame by varying load conditions

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