# UNIVERSITI MALAYSIA PAHANG

## BORANG PENGESAHAN STATUS TESIS ◆

**JUDUL: DESIGN AND ANALYSIS OF A NEW RACING BICYCLE FRAME**

**SESI PENGAJIAN: 2008/2009**

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DESIGN AND ANALYSIS OF A NEW RACING BICYCLE FRAME

RAHMAT BIN NOOR YATIM

A report submitted in partial fulfillment of the requirements
for the award of the degree of
Bachelor of Mechanical Engineering with Manufacturing

Faculty of Mechanical Engineering
UNIVERSITI MALAYSIA PAHANG

NOVEMBER 2008

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We hereby declare that we have checked this project and in our opinion this project is satisfactory in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering with Manufacturing

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I hereby declare that the work in this thesis is my own except for quotations and summaries which have been duly acknowledged. The thesis has not been accepted for any degree and is not concurrently submitted for award of other degree.

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## DEDICATION

*To my beloved father,*

*Noor Yatim bin Yahaya*

*My beloved mother,*

*Normah binti Ibrahim*

*and*

*All my beloved family members*

*Thank you for every single thing*

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My fellow colleagues should also be recognized for their support and friendship. My deeply thanks also goes to others who have provided assistance at various occasions that invite whether direct or indirectly in the completion of my project. Last, but certainly not least, my special thanks also extends to my family for the continual encouragement and support.

## ABSTRACT

This project is to design and analysis of a new racing bicycle frame. There are too many designs in market today but they have their own advantages and disadvantages. This project will study about the current designs and also design a new racing bicycle frame that improved the current. At first this project will study about five current designs to see the advantages. Then it will combine the advantages and improve some properties before create a new design. The design will use Solidworks software and the analysis will use Algor software. The parameter for this project is human weight between 50kg to 80kg. The result from the analysis will show the critical part on the design and value of the displacement, stress and strain.

# ABSTRAK

Projek ini mencipta lukisan baru bagi basikal lumba dan menganalisis lukisan tersebut. Terdapat banyak ciptaan yang pelbagai bentuk dan rekaan bagi basikal lumba yang terdapat dalam pasaran sekarang. Tetapi setiap rekaan tersebut mempunyai kelebihan dan juga kekurangannya sendiri. Projek ini akan melihat dan mengkaji beberapa rekaan yang terdapat dalam pasaran dan mengambil kelebihan-kelebihan yang terdapat pada rekaan tersebut. Melalui itu, kelebihan-kelebihan setiap rekaan akan digabungkan dan dinaik taraf bagi menghasilkan rekaan baru yang lebinh baik dari yang sedia ada. Rekaan rangka basikal akan menggunakan perisian 'Solidworks' dan analisis rangka basikal akan menggunakan perisian 'Algor'. Parameter bagi projek ini adalah berat penunggang basikal diantara 50kg hingga 80kg. Keputusan dan data yang diperolehi dari analisi akan menunjukkan kita bahagian rekaan yang lemah dan perlu diubah suai. Data-data yang terkumpul juga akan dimasukkan ke dalam graf bagi melihat hubungan di antara satu sama lain.

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# CHAPTER 1

# INTRODUCTION

## 1.1 PROJECT BACKGROUND

The technology on bicycle designing and developing process is growing up proportional to the new coming era. As knowledge becomes essential ingredients for a design success, there is much company that builds up to challenge in their technology. The book title `Bicycle *Frame'* written by Kossak and Joe is one of the early reference books on bicycle technology. As we know, bicycle is the transport that created to help people move faster to a place. But, as the early, bicycle is just use to move at the near place only. Nowadays, bicycle not just for help people to move but it become one of the famous sport game in the world.

Who did not know the games that named as `Tour de France', `Tour de Italy', and in our country also 'Le Tour de Langkaw=i'. All of this game is the challenging for the best bicycle to win. But, what is the best bicycle mean? The best bicycle covers the design, support, promotion and the rider, From this element, the most important thing is the design of the bicycle. Why design important? We know that every vehicle have their own reason why it can be shape like that. All vehicles must have aerodynamic shape to make sure that the vehicle can travel smoothly and faster. For additional, electronic shifting system which was pioneered in Tour de France by American Greg Le Mond in the mid 1990's.

The most important thing about a racing bicycle is its weight and the aerodynamic efficiency of the rider's position. Drop handle bars and optional handle bars extension are combined with a raised seat in order to put the rider in a more aerodynamic posture. The front and back wheels must be close together to make sure that the bicycle can turn very quickly. This statement follows the Revisionist theory of bicycle sizing by Sheldon Brown.

This project will cover about literature review, research, design and also analysis of a new racing bicycle frame. The new design should have improvement if compare to the current design in the market.

## 1.2 PROBLEM STATEMENT

The designer should improve their design in order to build up a new model that can be more efficient and more perfect. There are too many design of racing bicycle in market today with different spec and material that they use. However each design has its own advantages and disadvantages. So that, the design that already in market should be improved. There are many factor that designer should consider to make sure that the new design become more perfect and effective.

In this project it will combine the design that already in market and see the advantages of each design. The new design will create after consider factor that important such as material, weight, and aerodynamic shape.

### 1.2.1 Current design

Today, there are many designs that we can see in the intend or some others information source. Each design has own reason or advantages why it should be like that. We can see the different between the designs from its shape, material that use, weight and others. The most important thing in designing a racing bicycle is the weight and the aerodynamic efficiency of the rider's position. We know that when the bicycle travels in high velocity, the bicycle and riders will go through the air flow. So, this will be the factor that will slow down the speed of the bicycle. This should be the one that will be considering seriously in designing a racing bicycle.

### 1.2.2 Solution for the problem

A new design will do based on the important factor for improvement. It will cover about to optimize the frame for weight, stiffness, and strength when the frame building process begin. In order to build up a light weight bicycle, we should consider about the material that will use. The most top material that use in current design is steel, aluminum, titanium or carbon. The second major factor is aerodynamic. This project will design in solid works and will be analyze use Algor software. Design also will consider about the posture of rider's to make sure that the bicycle will travel smoothly prevent the air resistance.

## 1.3 PROJECT OBJECTIVES

The purposed of these projects are to study about the current design in the market and improve it. The objectives of the project are:

1. To design a new racing bicycle frame.
2. To analyze the design.

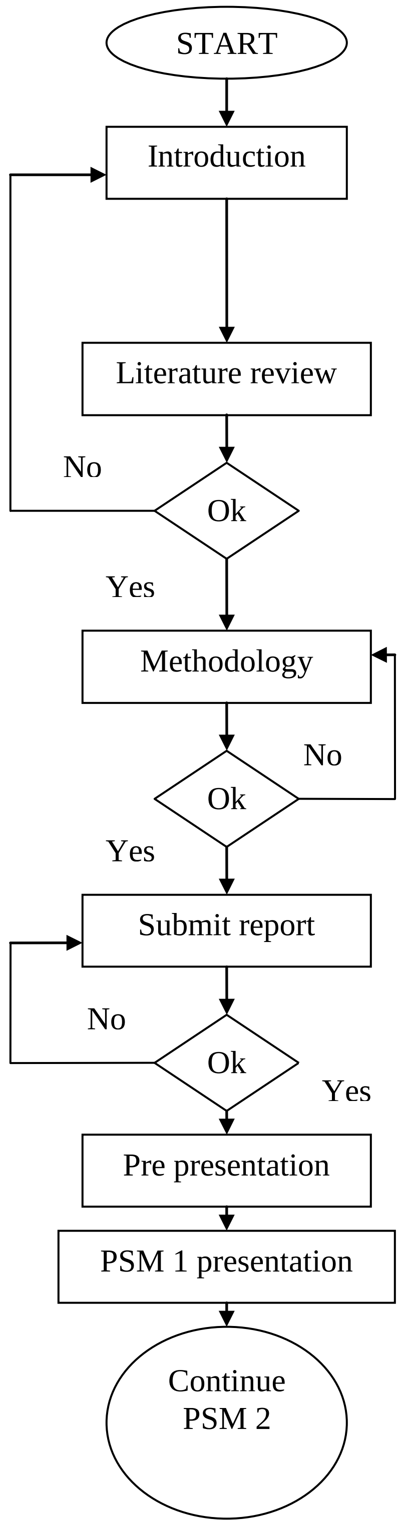
## 1.4 PROJECT SCOPES

This project is designing and analyzing a new racing bicycle frame to improve the design that already in the market. The design will use solid works software. Analysis frame and material will use Algor software which can perform finite element analysis. Besides, this project is cover for:

1. Literature review for current design to see the advantages and disadvantages.
2. Design new racing bicycle frame use Solid works software.
3. Analyze the design use Algor software.

## 1.5 PROJECT PLANNING

The planning for “Design and analysis of a new racing bicycle frame” is presented in this section. This planning consists of Flow chart PSM 1, Flow chart PSM 2, Gantt chart PSM 1 and Gantt chart PSM 2, which is shown in Figure 1.1, Figure 1.2, Figure 1.3 and Figure 1.4.




- Set the objective and scope.
- Determine the problem statement,
- Determined the previous method used.
- 5 current design
- Design using Solidworks

**Figure 1.1** Flowchart for PSM 1.

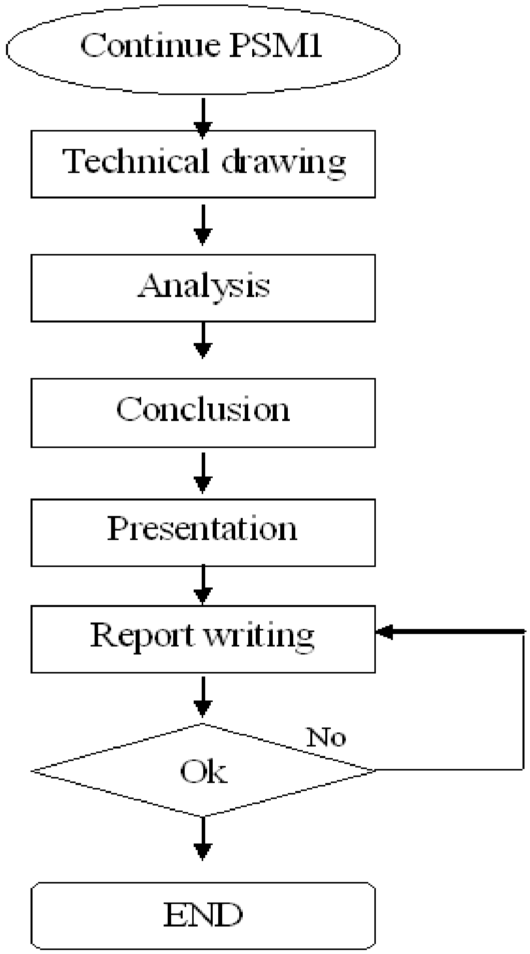



**Figure 1.2** Flowchart for PSM 2.

| Project activities | W1 | W2 | W3 | W4 | W5 | W6 | W7 | W8 | W9 | W10 | W11 | W12 | W13 | W14 | W15 | W16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **INTRODUCTION** | | | | | | | | | | | | | | | | |
| Project briefing | √ | √ | | | | | | | | | | | | | | |
| Objective and scope | √ | √ | | | | | | | | | | | | | | |
| Problem statement | | | √ | | | | | | | | | | | | | |
| Flowchart | | | | √ | | | | | | | | | | | | |
| **LITERATURE REVIEW** | | | | | | | | | | | | | | | | |
| Internets and books | | | | √ | √ | √ | √ | | | | | | | | | |
| Previous method | | | | √ | √ | √ | √ | | | | | | | | | |
| Parameters used | | | | √ | √ | √ | √ | | | | | | | | | |
| Data of 5 current design | | | | | | | √ | √ | √ | √ | | | | | | |
| Bicycle basic part | | | | | | | √ | √ | √ | √ | √ | | | | | |
| material | | | | | | | | | | √ | √ | √ | | | | |
| **METHODOLOGY** | | | | | | | | | | | | | | | | |
| Literature review | | | | | | | | | √ | √ | √ | √ | | | | |
| Sketching and designing | | | | | | | | | | | √ | √ | √ | √ | | |
| **SUBMIT AND REWRITE** | | | | | | | | | | | | | | | | |
| Submit report PSM 1 | | | | | | | | | | | | | √ | √ | | |
| Rewrite report PSM 1 | | | | | | | | | | | | | √ | √ | | |
| **FINAL 1** | | | | | | | | | | | | | | | | |
| Pre-presentation | | | | | | | | | | | | | | | √ | √ |
| PSM 1 presentation | | | | | | | | | | | | | | | √ | √ |

**Figure 1.3** Gantt chart for PSM 1.

| Project activities | W1 | W2 | W3 | W4 | W5 | W6 | W7 | W8 | W9 | W10 | W11 | W12 | W13 | W14 | W15 | W16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **RESULT AND DISCUSSION** | | | | | | | | | | | | | | | | |
| designing | √ | √ | | | | | | | | | | | | | | |
| Simulation | | √ | √ | | | | | | | | | | | | | |
| Analysis | | | √ | √ | √ | | | | | | | | | | | |
| Displacement | | | | | √ | √ | | | | | | | | | | |
| Stress | | | | | | √ | √ | | | | | | | | | |
| Strain | | | | | | | | √ | √ | | | | | | | |
| Compare result | | | | | | | | | | √ | | | | | | |
| Discussion | | | | | | | | | | | √ | | | | | |
| **CONCLUTION** | | | | | | | | | | | | | | | | |
| Recommendation | | | | | | | | | | | | √ | | | | |
| Conclude project | | | | | | | | | | | | | √ | | | |
| **SUBMIT AND REWRITETEN** | | | | | | | | | | | | | | | | |
| Submit final report | | | | | | | | | | | | | | √ | | |
| Rewritten final report | | | | | | | | | | | | | | | √ | |
| **FINAL** | | | | | | | | | | | | | | | | |
| Final presentation | | | | | | | | | | | | | | | | √ |

**Figure 1.4** Gantt chart for PSM 2.

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 INTRODUCTION

Frame is the main component of a bicycle and fitted with wheels and other component. The modem and most common frame is made of two triangles, a main triangle and a paired rear triangle. This is known as diamond frame. The main triangle consists of the head tube, top tube, down tube and seat tube. The rear triangle consists of the seat tube, and paired chain stays and seat stays. The head tube contains the headset, the interface with the fork. The top tube connects the head tube to the seat tube at the top, and the down tube connects the head tube to the bottom bracket shell. The rear triangle connects to the rear dropouts, where the rear wheel is attached. It consists of the seat tube and paired chain stays and seat stays. The chain stays run parallel to the chain, connecting the bottom bracket to the rear dropouts. The seat stays connect the top of the seat tube to the rear dropouts.

## 2.2 BICYCLE FRAME

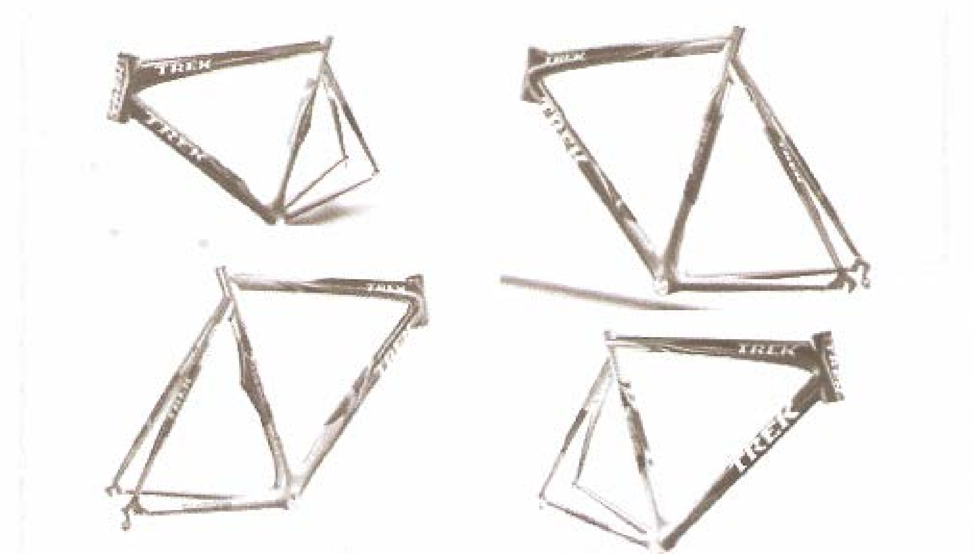


**Figure 2.1** Bicycle frame

### 2.2.1 Frame tubes

The most common used frame (diamond frame) consists of two triangles, a main triangle and a paired rear triangle. The main triangle consists of the head tube, top tube, down tube and seat tube. The rear triangle consists of the seat tube, and paired chain stays and seat stays.

### 2.2.2 Head tubes

The head tube contains the headset, the interface with the fork. In an integrated treadles headset, the bearings interface directly with the metal surface on the inside of the head tube.

### 2.2.3 Top tubes

The top tube connects the head tube to the seat tube at the top. In a mountain bike frame, the top tube is almost always sloped. In a traditional-geometry racing bicycle frame, the top tube is horizontal. In a compact-geometry frame, the top tube is sloped.

Control cables are routed along mounts on the top tube. Most commonly, this includes the cable for the rear brake, but some mountain bikes and hybrid bicycle also route the front and rear derailleur cables along the top tube.

The space between the top tube and the rider's groin while straddling the bike and standing on the ground is called clearance. The total height from the ground to this point is called the stand over height.

### 2.2.4 Down tubes

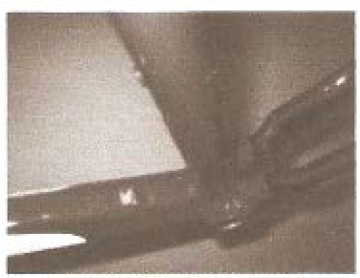


Figure 2.2 : Down tube

The down tube connects the head tube to the bottom bracket shell. On racing bicycles and some mountain and hybrid bikes, the derailleur cables run along the down tube. On older racing bicycles, the gear levers were mounted on the down tube. On newer ones, they are integrated with the brake levers on the handlebars.

Bottle cage mounts are also on the down tube. In addition to bottle cages, small air pumps may be fitted to these mounts as well.

### 2.2.5 Seat tubes

The seat tube contains the seatpost of the bike, which connects to the saddle. The saddle height is adjustable by changing how far the seatpost is inserted into the seat tube. On some bikes, this is achieved using a quick release lever. The seatpost must be inserted at least a certain length; this is marked with a minimum insertion mark. The seat tube also may carry bottle cage mounts.

### 2.2.6 Chain stay

The chain stays run parallel to the chain, connecting the bottom bracket shell to the rear dropouts. When the rear derailleur cable is routed partially along the down tube, it is also routed along the chain stay. The chain stays provide a mount for rear disc brakes.

### 2.2.7 Seat stay

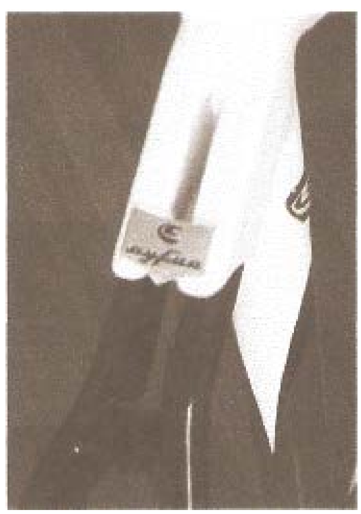


**Figure 2.3** Seat stay

The seat stays connect the top of the seat tube to the rear dropouts. When the rear derailleur cable is routed partially along the top tube, it is also routed along the seat stay.

One combination aluminum/carbon fiber racing frame design uses carbon fiber for the seat stays and aluminum for all other tubes. This takes advantage of the better vibration absorption of carbon fiber compared to aluminum.

A single seat stay refers to seat stays which merge onto one section before joining the front triangle of the bicycle, thus meeting at a single point. A dual seat stay refers to seat stays which meet the front triangle of the bicycle at two separate points, usually side-by-side. The seat stays also provide a mounting point for the rear rim brakes.

## 2.3 CURRENT DESIGN

### 2.3.1 Felt F1C

**Figure 2.4** Felt F l C

| | |
|---|---|
| MODEL | FELT FIC |
| COLOR | Matter Clear over Carbon |
| SIZES | 700c x 52,54,56,58,60 |
| FRAME | Ultra-High Modulus Modular Carbon Fiber Frame with 3K Weave |
| FORK | Reynolds Ouzo Pro Integrated, 100% Carbon Monoquce Design, 1-1/8" Carbon Steerer |
| HEADSET | FSA 1-1/8" Integrated |
| STEM | Felt ST-21 CNC'd 7075AL with 5° Rise and Ti Bolts |
| HANDLEBAR | FSA K-WING 100% Carbon/Kevlar Composite Wing Shape, O31.8mm |
| SHIFTERS | Shimano Dura-Ace, 20 speed |
| F/DERAILLUER | Shimano Dura-Ace |
| R/DERAILLUER | Shimano Dura-Ace |
| CRANKSET | Shimano Dura-Ace, 53/39T |
| CHAIN | Shimano 10-Speed |
| FREEWHEEL | Shimano 10-Speed Cassette, 11-23T |
| BRAKE LEVERS | Shimano Dura-Ace Dual Control |
| BRAKES | Shimano Dura-Ace |
| SADDLE | Felt Race-Lite with Carbon Injected Base and Leather Cover with CrN/Ti Rails |
| SEAT POST | Ritchey WCS Carbon |
| F/HUB | Mavic Ksyrium ES Carbon, 18H |
| R/HUB | Mavic Ksyrium ES, 20H |

| | |
|---|---|
| RIMS | Mavic Ksyrium ES ISM Machined Maxtal, Low Profile with UB Control |
| TIRE | Vittoria Diamante Pro-Light Folding 700x23c |
| SPOKES | Mavic Ksyrium ES Flat Zircal |
| PEDAL | none |

**Table 2.1** Felt F 1 C properties

### 2.3.2 Bottecchia

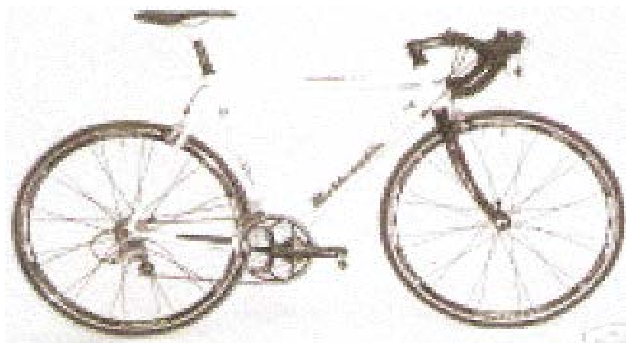


**Figure 2.5** Bottecchia

| | |
|---|---|
| FRAME | COLUMBUS ZONAL TRIPLE BUTTED 7005 ALUMINUM WITH SMOOTH WELDING |
| FORK | BOTTECCHIA CARBON-FIBER 1-1/8" FITTED WITH FSA ORBIT-X AHEADSET |
| WHEELSET | VUETA XRP PRO 30mm RIM W/ AERO 24/24 SPOKES W/ PRECISION SEALED BEARINGS |
| TIRES | KENDA 23c DUAL COUMPOND BLK/RED/BLK |
| CRANK | FSA GOSSAMAR TRIPLE 52x42X30T ISIS |
| PEDALS | BOTTECCHIA SPD ALLOY |
| SHIFTERS | SHIMANO ST-4400 SHIFTER/BRAKE LEVER |
| BRAKES | CANE CREEK SCR3 DUAL PIVOT COLD FORGED |
| FRONT DER | SHIMANO FD-4500 |
| REAR DER | SHIMANO 105 GS |
| CASSETTE | SHIMANO HG50-9 12/27T |
| CHAIN | KMC Z9000 |
| HANDLEBARS | VUELTA XRP PRO 31.8 OS 6061 ALLOY |
| STEM | VUELTA XRP PRO 31.8 OS 6061 ALLOY |
| SEAT POST | VUELTA XRP PRO 27.2 x 300mm 6061 ALLOY |

| | |
|---|---|
| SADDLE | BOTTECCHIA |

**Table 2.2** Bottecchia poperties

### 2.3.3 Fuji Roubaix

**Figure 2.6** Fuji Roubaix

| | |
|---|---|
| MODEL | FUJI ROUBAIX |
| COLOR | none |
| SIZES | 49cm, 52cm, 54cm, 56cm, 58cm, 61cm, 64cm |
| FRAME | Alloy Steerer Frame Composition Fuji Altair 2 Lite |
| FORK | Fuji Lightweight 1 1/8" Carbon Road |
| SHIFTERS | Shimano 105 (front), Ultegra (rear) |
| F/DERAILLUER | Fuji forged road |
| R/DERAILLUER | Fuji forged road |
| CRANKSET | Shimano 105 |
| CHAIN | Fuji Altair 1 aluminum |
| FREEWHEEL | Shimano 10-Speed Cassette, 11-23T |
| BRAKE LEVERS | Shimano 105 |
| BRAKES | Shimano 105 |
| SADDLE | none |
| SEAT POST | Fuji Carbon |
| F/HUB | Speeds 27 Quick-Release |
| R/HUB | Ritchey Comp Road |
| RIMS | Ritchey OCR Pro Road, 28H rims |
| TIRE | Continental Sport 1000 |
| SPOKES | 105 STI levers |
| PEDAL | none |

**Table 2.3** Fuji Roubaix properties

### 2.3.4 Felt F90

**Figure 2.7** Felt F90

| | |
|---|---|
| MODEL | F90 |
| COLOR | Bright Red |
| SIZES | 650c x 47; 700 x 50, 52, 54, 56, 58, 60, 63 |
| FRAME | Felt 7005 F-Lite Double-butted aluminum frame w/forged dropouts and replaceable hanger |
| FORK | Reynolds Ouzo Pro Integrated, 100% Carbon Monoquce Design, 1-1/8" Carbon Steerer |
| HEADSET | Aheadset 1-1/8" |
| STEM | Felt ST 6061 3D Forged with 7° Rise |
| HANDLEBAR | Felt Alloy Ergonomic Drop, O31.8mm |
| SHIFTERS | Shimano Sora, 24 –Speed |
| F/DERAILLUER | Shimano Sora |
| R/DERAILLUER | Shimano Tiagra |
| CRANKSET | FSA/RPM 3-PC Alloy, 52/42/30T |
| CHAIN | Z92 Silver |
| FREEWHEEL | Shimano 8-Speed Cassette, 12-25T |
| BRAKE LEVERS | Shimano Sora Dual Control with Tektro Bar Top Levers |
| BRAKES | Dual Pivot with New and Improved Brake Pads |
| SADDLE | Felt Gel-Lite |
| SEAT POST | Felt Carbon/Alloy Micro-Adjust |
| F/HUB | Felt Aluminum Hub with Sealed Bearing and Aluminum QR, 32H |

| | |
|---|---|
| R/HUB | Felt Aluminum Hub with Sealed Bearing and Aluminum QR, 32H |
| RIMS | Alex ALX-R450 Aluminum Double-Wall Rims with CSW Braking Surface |
| TIRE | Vittoria Action HSD 700x23c |
| SPOKES | Stainless 14G |
| PEDAL | Aluminum Pedal with Clips and Straps |

**Table 2.4** Felt F90 properties

### 2.3.5 Speedmax

**Figure 2.8** Speedmax

| | |
|---|---|
| MODEL | SPEEDMAX DSR-7009 |
| COLOR | none |
| SIZES | none |
| FRAME | *26" 700c* alloy frame |
| FORK | steel fork |
| HEADSET | eight steel head sets CP |
| STEM | alloy |
| HANDLEBAR | half alloy |
| SHIFTERS | F2 *R6 SIS* (Sunrace brand) |
| F/DERAILLUER | F/TYI8, R/TY18GS Shimano |
| R/DERAILLUER | F/TY18, R/TYI8GS Shimano |
| CRANKSET | Shimano |
| CHAIN | Z30 KMC |
| FREEWHEEL | Shimano TZ06 |
| BRAKE LEVERS | steel with hand protection (Apse brand) |
| BRAKES | racing style |
| SADDLE | racing style |
| SEAT POST | steel CP |
| F/HUB | steel hub (Assess factory) |
| R/HUB | steel hub (Assess factory) |
| RIMS | tri wall alloy rims |
| TIRE | Innova |
| SPOKES | UCP |

| | |
|---|---|
| PEDAL | full alloy |

**Table 2.5** Speedmax properties

### 2.3.6 Advantages of five current design

| MODEL | ADVANTAGES |
|---|---|
| Felt 1 C | • Light weight<br>• Ultra high modulus carbon material<br>• Gravity defying, incredibly smooth and balance ride<br>• Every cross section has been optimize in size and shape to maximize speed and minimize weight |
| Bottecchia | • Columbus zonal areo tubing, triple-butted with smooth weld technology to ensure top performance without a harsh ride.<br>• Carbon fiber fork (absorb shock)<br>• FSA Triple Compact Crankset to provide a wide range of gearing for those who prefer a triple |
| Fuji Roubaix | • Light weight (19.7 pounds)<br>• Fast ride in hill climbing<br>• Combination of carbon fiber (front fork and seat stay) and 7000 series aluminum alloy<br>• The combination is stiff, lightweight and absorb road shock |
| Felt F90 | • Double-butted aluminum Tubing<br>• Carbon fiber fork<br>• Forged dropouts with replaceable hanger |

| | |
|---|---|
| Speedmax | • Light weight<br>• Aerodynamic<br>• Strong frame (alloy) |

**Table 2.6** Advantages of five designs

## 2.4 FRAME GEOMETRY

Frame geometry means the length of the tubes, and the angles at which they are attached. In comparing different frame geometries, designers often compare the seat tube angle, head tube angle, top tube length, and seat tube length. To complete the specification of a bicycle for use, the rider usually specifies:

- saddle height, the distance from the center of the bottom bracket to the point of reference on top of the saddle 13cm from the rear of the saddle.
- reach, the distance from the saddle to the handlebar.
- drop, the vertical distance between the references at the top of the saddle to the handlebar.
- setback, the horizontal distance between saddle reference point and the center of the bottom bracket.

The geometry of the frame depends on the intended use. For instance, a road bicycle will place the rider in a lower, more crouched position; whereas a utility bicycle emphasizes comfort and has an upright seating position. Geometry also affects handling characteristics. Frame geometries in which the wheelbase is shorter are quicker in cornering but harder to balance. In some instances frame geometries can contribute to high-speed wobble.

### 2.4.1 Frame size

Frame size was traditionally measured from the center of the bottom bracket to the top of the seat tube. Typical "medium" sizes are 21 or 23 inches (approximately 53 or 58 cm) for a European men's racing bicycle or 18.5 inches (about 46 cm) for a men's mountain bicycle. The wider ranges of frame geometries that are now made have given rise to different ways of measuring frame size. Touring frames tend to be longer, while racing frames are more compact.

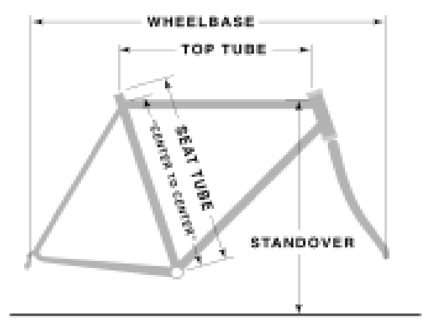



**Figure 2.9** Commonly use measurement

## 2.5 FRAME MATERIAL

Material selection process also very important in order to make sure that we get the suitable material for our design. The material that will choose must follow the properties that we have decided for the bicycle. Before select the material, we must know the properties of the material and compare to the other material to see the advantages and disadvantages.

What is the best material to use in building a bicycle frame - steel, aluminum, titanium or carbon fiber? What material properties are important in choosing bicycle frame material? First, there are three types of material properties:

- Physical - Density, color, electrical conductivity, magnetic permeability, and thermal expansion.
- Mechanical - Elongation, fatigue limit, hardness, stiffness, shear strength, tensile strength, and toughness.
- Chemical - Reactivity, corrosion resistance, electrochemical potential, irradiation resistance, resistance to acids, resistance to alkalis, and solubility.

### 2.5.1 Material properties

Generally, the tubes of the frame are made of steel. Steel frames can be very inexpensive carbon steel to highly specialised using high performance alloys. Frames can also be made from aluminum alloys, titanium, carbon fiber, and even bamboo. Occasionally, diamond frames have been formed from sections other than tubes. These include I-beams and monocoque. Materials that have been used in these frames include wood (solid or laminate), magnesium (cast I-beams), and thermoplastic. Several properties of a material help decide whether it is an appropriate in the construction of bicycle frame.

#### 2.5.1.1 Density

Density is how much a material weight for a given volume. This is an important and easy relationship to remember: Titanium is about 1:2 the density of steel, aluminum is about 1:3 the density of steel.

#### 2.5.1.2 Stiffness

The measurement for stiffness is called modulus of elasticity, or Young's modulus. Young's Modulus is the ratio of stress-to-strain in the region below the proportional limit on the stress-strain curve. Young's modulus doesn't change with different alloys or heat treatments of the same metal.

#### 2.5.1.3 Elongation

I know that this sounds like an exciting property, but it's not. Elongation measures how far a material will stretch before it breaks. It's a measure of the material's ductility. What's ductility? It's the ability of a material to deform plastically without fracturing. What's plastic deformation? It's when a material deforms when a load is applied, and remains deformed after the load is released (bending).

#### 2.5.1.4 Tensile strength

Tensile strength is the test used to determine the bending and breaking point of the specimen is done by pulling the sample apart (applying tension).

#### 2.5.1.5 Fatigue strength

The fatigue strength is a measure of the stress at which a material fails after a specific number of cycles. Fatigue failure occurs by applying cyclic stress of a maximum value less than the static tensile strength of the material until your specimen fails. This can be a cool test, because the alternating stress mimics vibrations and impacts that happen when you ride your bicycle down the long and winding road.

#### 2.5.1.6 Toughness

This is the ability of a metal to absorb energy and deform plastically before fracturing. A tough metal is more ductile and deforms rather than fracturing in a brittle manner - particularly in the presence of stress raisers such as cracks and notches.

### 2.5.2 Comparison of Material Properties

| Properties | Stainless steel | Aluminum | Titanium | Carbon fiber |
|---|---|---|---|---|
| Density ($kg/m^3$) | 7750-8100 | 2600-2800 | 4510 | |
| Melting point (°C) | 1371-1454 | 660 | 1668 | |
| Elastic modulus (GPa) | 190-210 | 70-79 | 100-120 | 69 |

| | | | | |
|---|---|---|---|---|
| Poison's ratio | 0.27-0.3 | 0.33 | 0.33 | |
| Tensile strength (MPa) | 276-1882 | 230-570 | 234 | 276-345 |
| Yield strength (MPa) | 186-758 | 215-505 | 138 | 207-276 |
| Percent elongation (%) | 10-32 | 10-25 | 54 | 1-2 |

**Table 2.7** Material properties

### 2.5.3 Material selection

There is no one of the materials described happen to be the perfect material to use, all have their advantages and disadvantages. Comparing and designing frames out of different materials is difficult because failure modes are so different. And welding, bonding, brazing, machining and finishing these materials are all accomplished differently.

Steel is a wonderfully reliable material for building bikes. It's safe to say that there's no more successful material ever used. It's easy to work with, can be easily welded or brazed, requires simple tools for fabrication, fails in a predictable manner (as opposed to sudden or catastrophic), and is cheap. There have been few challengers to steel's throne of best material in the last 100 years. For a couple of decades, we have seen aluminum increasingly being used in bikes, and titanium has been used successfully for about 10 years. But steel is being seriously challenged by an increasing array of promising new materials.

## 2.6 Type of bicycle

### 2.6.1 Road bicycle

A road racing bicycle is designed for efficient power transfer at minimum weight and drag. Broadly speaking, the road bicycle geometry is categorized as either a traditional geometry with a horizontal top tube, or a compact geometry with a sloping top tube.

Traditional geometry road frames are often associated with more comfort and greater stability, and tend to have a longer wheelbase which contribute to these two aspects. Compact geometry road frames have lower center of gravity and tend to have shorter wheelbase and smaller rear triangles, which make the handling to be quicker. Compact geometry also allows the top of the head tube to be above the top of the seat tube, increasing standover clearance, and lowering the center of gravity. Opinion is divided on the riding merits of the compact frame, but several manufacturers claim that a reduced range of sizes can fit most riders, and that it is easier to build a frame without a perfectly level top tube.

Road bicycles for racing tend to have a steeper seat tube angle, measured from the horizontal plane. Touring and comfort bicycles tend to have slacker seat tube angle. The slacker angle forces the rear wheel to be further behind the rider, thus contributing to shock absorption.

### 2.6.2 Triathlon or time trial bicycle

Triathlon or time trial specific frames rotate the rider forward around the axis of the bottom bracket of the bicycle as compared to the standard road bicycle frame. The reason for this is to put the rider in an even lower, more aerodynamic position. While handling and stability is reduced, these bicycles are designed to be ridden in environments with less group riding aspects. These frames tend to have steep seat tube angles and low head tubes, and shorter wheelbase for the correct reach from the saddle to the handlebar.

### 2.6.3 Track bicycle

Track frames have much in common with road and time trial frames, but come with rear facing fork ends that allow one to adjust the position of the rear wheel horizontally to set the proper chain tension.

### 2.6.4 Mountain bicycle

For ride comfort and better handling, shock absorbers are often used there are a number of variants, including full suspension models, which provide shock absorption for the front and rear wheels; and front suspension only models (hardtails) which deal only with shocks arising from the front wheel. The development of sophisticated suspension systems in the 1990s quickly resulted in many modifications to the classic diamond frame.

Recent mountain bicycles with rear suspension systems have a pivoting rear triangle to actuate the rear shock absorber. There is much manufacturer variation in the frame design of full-suspension mountain bicycles and different designs for different riding purposes.

### 2.6.5 Variations

There are other variations on the basic diamond frame design. Historically, women's bicycle frames had a top tube that connected in the middle of the seat tube instead of the top, resulting in a lower stand over height. This was to allow the rider to dismount while wearing a skirt or dress. This is also known as a step-through frame.

# CHAPTER 3

# METHODOLOGY

## 3.1 INTRODUCTION

At the beginning of this project, the title was selected and states the objective, scope of project and justification. The title is "Design and Fabrication of New Racing Bicycle Frame". Generally this project is focus on design a new racing bicycle frame that improves the current design in market. There are too many design of racing bicycle in the market. We should analyze some of the design to get information about the advantages and disadvantages of the design.

The methodology of this project is start with literature review which is state the all information from previous design and research from internet and book. For sketching, it will do after compare five current designs to get the better structure. This process will follow with the drawing process which uses Solid works software. The design will follow the parameter in the sketching process. After finish designing, the design will transfer to Finite Element Analysis (FEA) software which is ALGOR for stress analysis on frame designed. Then, the data that get from the analysis will transfer to get the graph.

## 3.2 LITERATURE REVIEW

Literature review will cover about the study of previous research had been performed to gain deeper knowledge about designing bicycle process and see the current design in the market. In this process, the information about previous research and current design get from the internet. From research, it will give information about design process and material that suitable for design a racing bicycle.

Review for five current designs is important to know about the properties and the advantages of current design. Then, the properties that not good will improve in new to get a better design in performance then before. This five current design also will compared to get the best value for each design to put in the new design.

This literature review also covers about the example of analysis for the bicycle frame. From research also we get knowledge about step-by-step on creating a racing bicycle. Mostly, the information get from internet which the designer and their engineer want to share their design process.

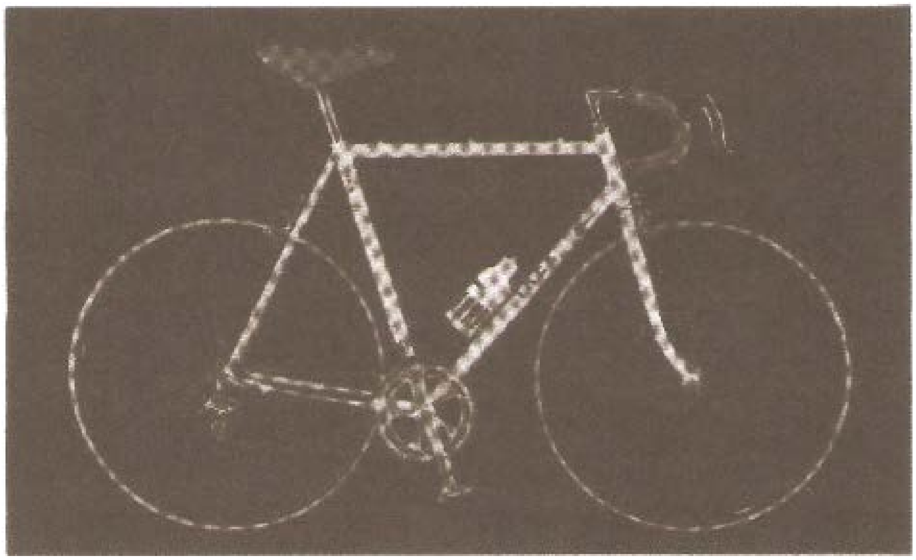


Figure 1: The **Trek** 2990 aluminum frame_ The design was **tine-tuned** with aid of finite-element analysis, by comparing it against the Trek 770 steel frame and the Vitus 979 aluminum frame imanufactured by Bador).

**Figure 3.1** Example of analysis

## 3.3 MATERIAL SELECTION

There is four type of material that most use for bicycle which is steel, aluminum, titanium, and carbon fiber. All of this material has their own characteristic and advantages like weight, strength and stiffness. But, designer should have their own reason why they choose that material. Every characteristic of material can give advantages on speed because of weight and reduce energy use by the rider when cycling.

However for this project, the material that will use is stainless steel. It because there's no more successful material ever used. It's also easy to work with, can be easily welded or brazed, requires simple tools for fabrication, fails in a predictable manner (as opposed to sudden or catastrophic), and is cheap.

For the analysis using Algor, Stainless Steel AISI (446) will use.

## 3.4 DRAWING PROCESS

In drawing process, it will cover about sketching, and drawing using solid works software. Firstly, a new design will sketch after analyze the current design and make some modification to improve the current design. This process will sketch about three designs. The sketching uses same material but different size, angle, and shape. The best design will select to continue the next process.

And then, after finish sketching and choose the best design, the sketched bicycle frame will draw in solid works software. Drawing will follow the sketch, but it will be some modification if necessary. The modification normally is for improvement in shape looking and surface finish.

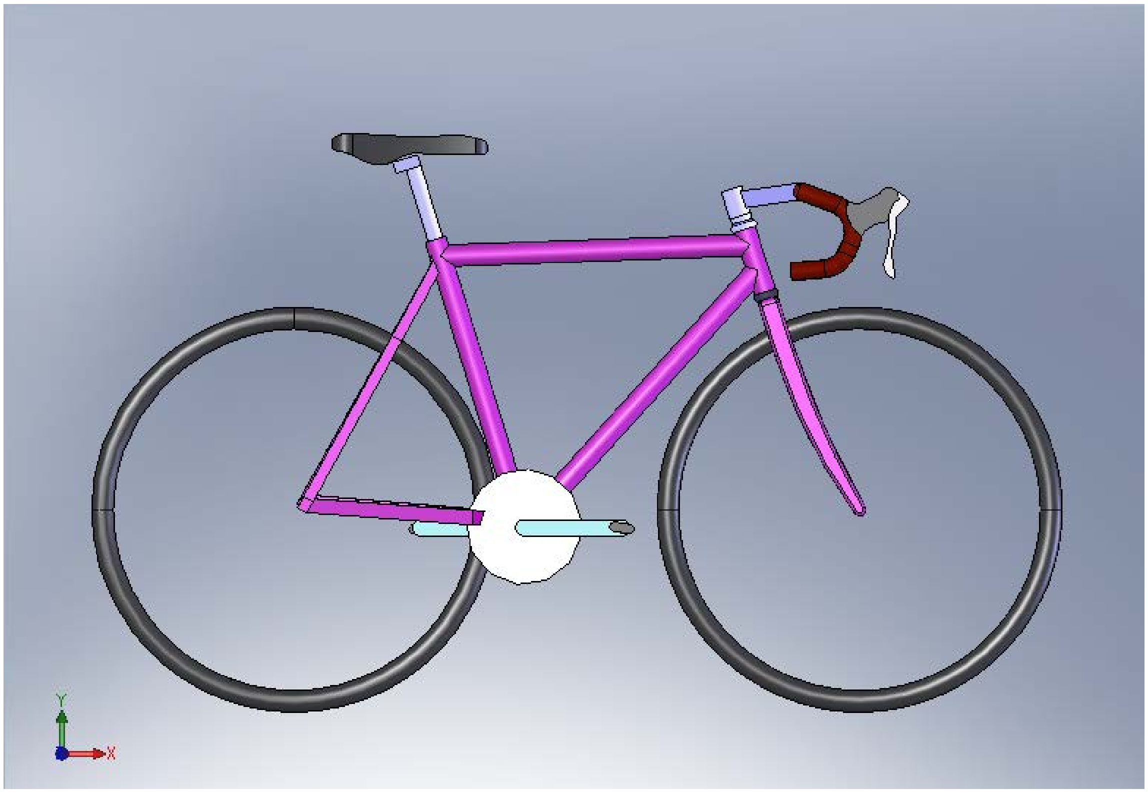



**Figure 3.2** New racing bicycle frame

### 3.4.1 Dimension of the design

The design actually follows one of the sketching that was choosing from three sketches. It not follow some value because of error when simulation. There is some modification on the value to make sure the design can be simulate without error. The figure shown above is the dimension that proportional to the value on the sketch.

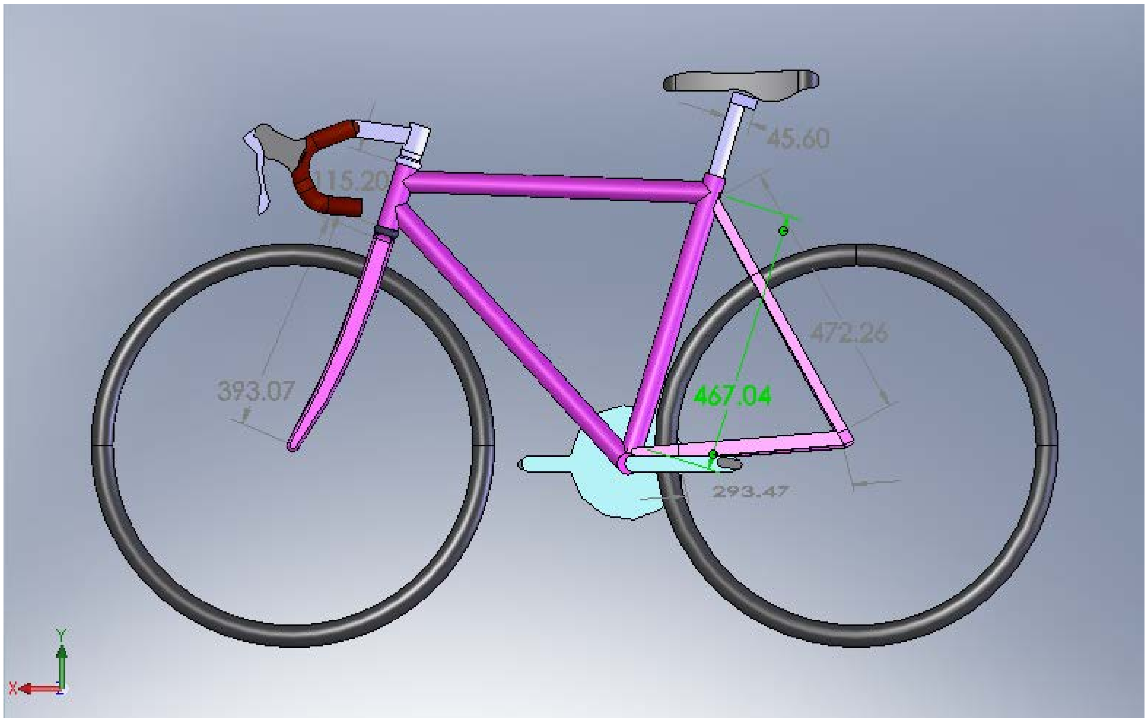



**Figure 3.3** Dimension of the design

## 3.5 ANALYSIS

After finish draw in solid works, the drawing will be transfer into Finite Element Analysis (FEA) software which is ALGOR for analysis process. From this process the value of stress, strain, displacement and other properties that important to show the advantages of this new design will get. If there is error for the design, the drawing will modified using solid works and then transfer back to analysis process. The process for analysis is should be as below:

- Construct a complete finite-elements model for the new frame design
- Apply a variety of loading conditions to all frames to calculate their response characteristics
- Identify which loading conditions are critical in the design, in terms of undesirable responses (high stresses, high deflections, etc.). Establish which loads may be safely ignored.
- Look for relationships between strength, stiffness, and weight by studying (graphing, plotting, etc.) the output data from the previous steps. Seek intuitive insights from the data about each frame's structural character.
- Recommend future designs, and apply the various critical load cases to gauge their performance.

### 3.5.1 Finite-element model

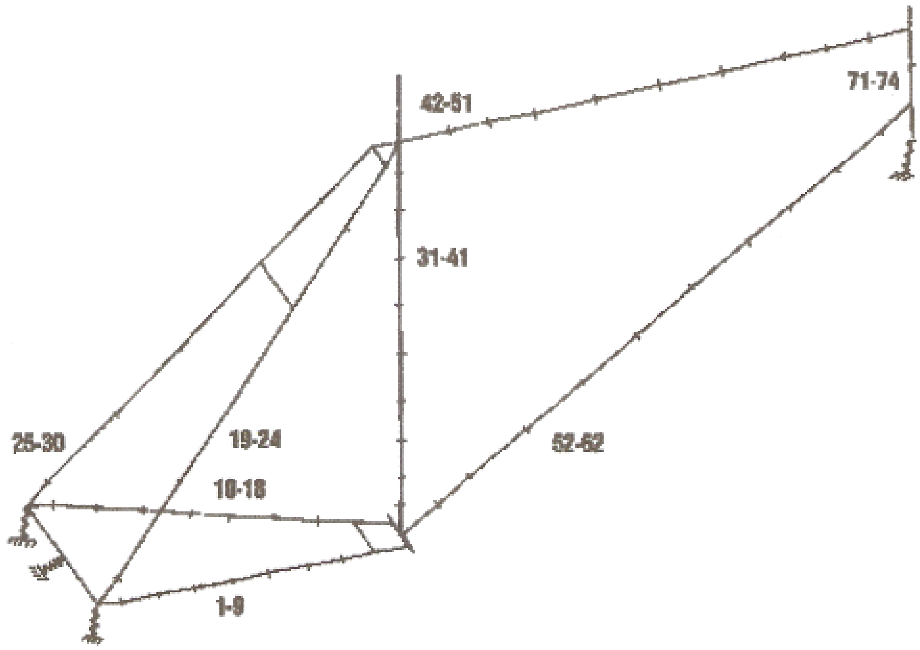



**Figure 3.4** Example of finite-elements model

The finite-element model is build by subdividing the frame into about 100 discrete beam elements. Boundary conditions are represented by restraints at rear axle and head tube.

### 3.5.1 Simulation

Firstly this design will simulate in Algor software. It will do after construct a complete finite-elements model for the design. Then this design will be analyze to see the displacement on the design. The load that will apply is human weight for 50kg, 60kg, 70kg, and 80kg.

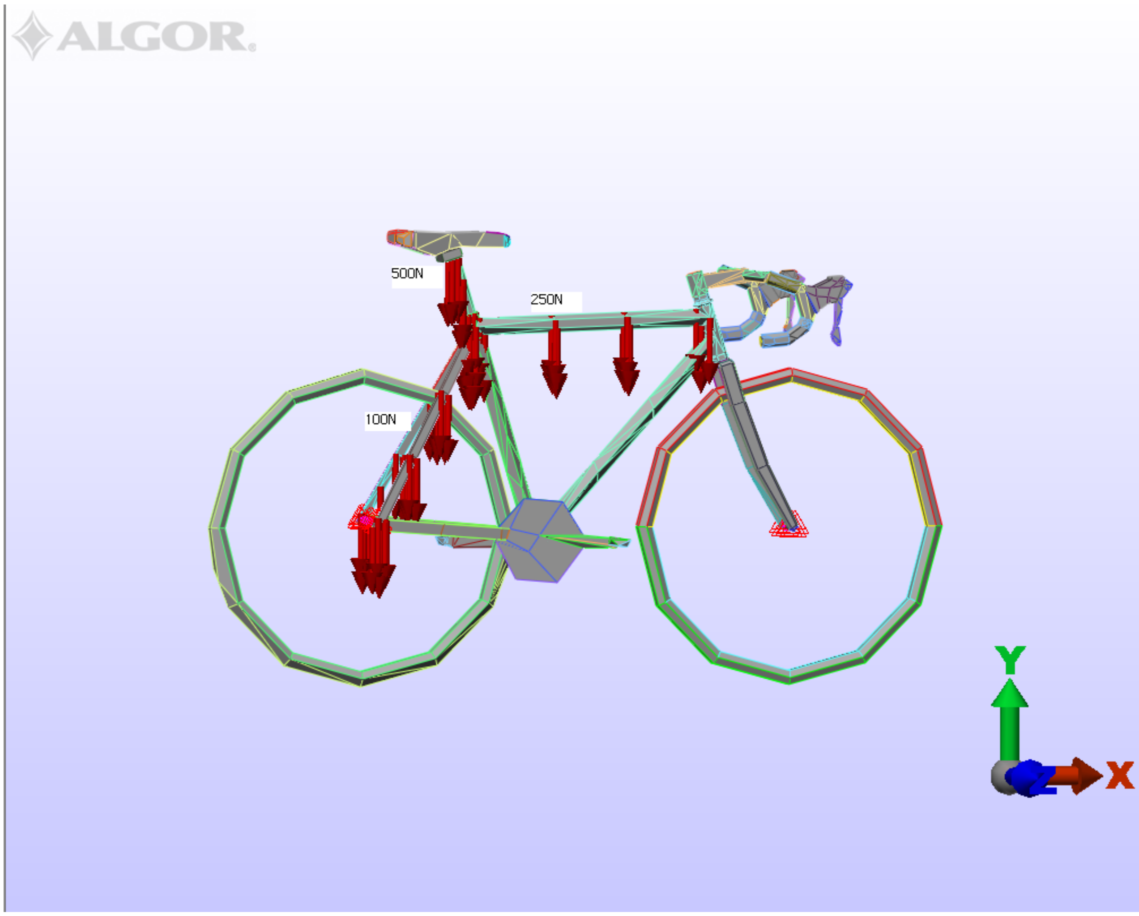



**Figure 3.4** Example of loads apply (50kg)

For this project the force is applied at three parts which is under the seat (at the seat adjustable lock), top tube and seat stay. At the top tube and seat stay it consider as equilibrium along the tube.

The boundary condition for this project is set up at the rear dropouts and at the fork of the bicycle

## 3.6 METHODOLOGY FLOW CHART

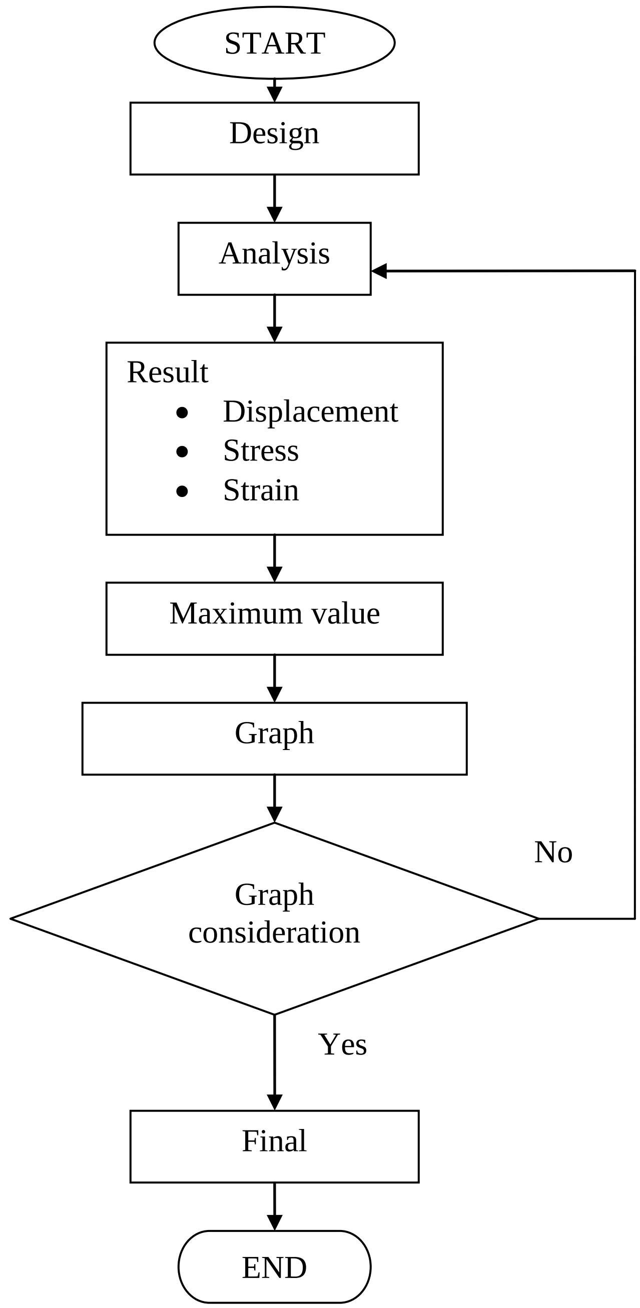



**Figure 3.4** Methodology flow chart for this project.

# CHAPTER 4

# RESULTS AND DISCUSSION

## 4.1 INTRODUCTION

This chapter will describe about simulation setup and also describe result from the analysis.

This chapter also describe about graph human weight which is between 50kg-80kg versus maximum value of displacement.

Before doing an analysis, fixed parameters and constraints is set up to identify the result. All of the parameters and constraints were taken from the previous experiment that was done by some designers. After that step of analysis method is applied using Algor software.

This thesis is create to identify the maximum value of displacement on the design to make sure that the critical point on the design can be improve after this.

## 4.2 SIMULATION OBJECTIVES

The simulation objective must be considered in this simulation. This is because the right setups of design and analysis parameters are required.

Design is one of the processes to produce product. Many parameters involve in this process. In the analysis, there is many data that can get and transfer into graph to see the response. This thesis will identify the critical point on the design for improvement after this experiment.

Selection of the material that will use for the bicycle development in the industrial also important. It is because the material can affect the cost on the production. We have to choose the best material that can be easy to handle, cheap and have a good properties to performance.

## 4.3 SIMULATION SETUP

In single-pass analysis problems, specification of the personal computer is considered because it will influence the simulation result. To make analysis run well the initial setup of computer also important. Other reason is to know the time taken for hundred iterations. This simulation using a 512 MB of Ram, 160 GB hard disc and Intel Core 2 Duo as a processor.

### 4.3.1 Material setup from Algor

Stainless Steel (AISI 446) - Plate

| | |
|---|---|
| Material Model | Standard |
| Material Source | Algor Material Library |
| Material Source File | C:\Program Files\ALGOR\MatLibs\algormat.mlb |
| Date Last Updated | 2004/09/30-16:00:00 |
| Material Description | Annealed |
| Mass Density | 7799.5 kg/m³ |
| Modulus of Elasticity | 199950000000 N/m² |
| Poisson's Ratio | .3 |
| Thermal Coefficient of Expansion | 0.00001152 1/°C |
| Shear Modulus of Elasticity | 77221000000 N/m² |

**Table 4.1** Stainless steel (AISI 446) properties

## 4.4 RESULT

The result that get from analysis are according to it steps. By using Algor software for simulation or analysis and considered objective functions also constraints and constant parameters the maximum value for the displacement, stress, and strain was generate for this thesis.

### 4.4.1 Analysis parameter

The parameter for this project is human weight. This is considering as the weight of the person or rider that will ride the bicycle. The parameter shown as below:

| PARAMETER | RANGE |
|---|---|
| Human Weight | 50kg-80kg |

**Table 4.2** Parameter

### 4.4.2 Analysis result

Analysis is the final procedure for this project. From the analysis, the data that collected will show the critical point at the design and also the maximum value of the displacement that will achieve the objective of this project.

## 4.5 RESULT FOR DISPLACEMENT

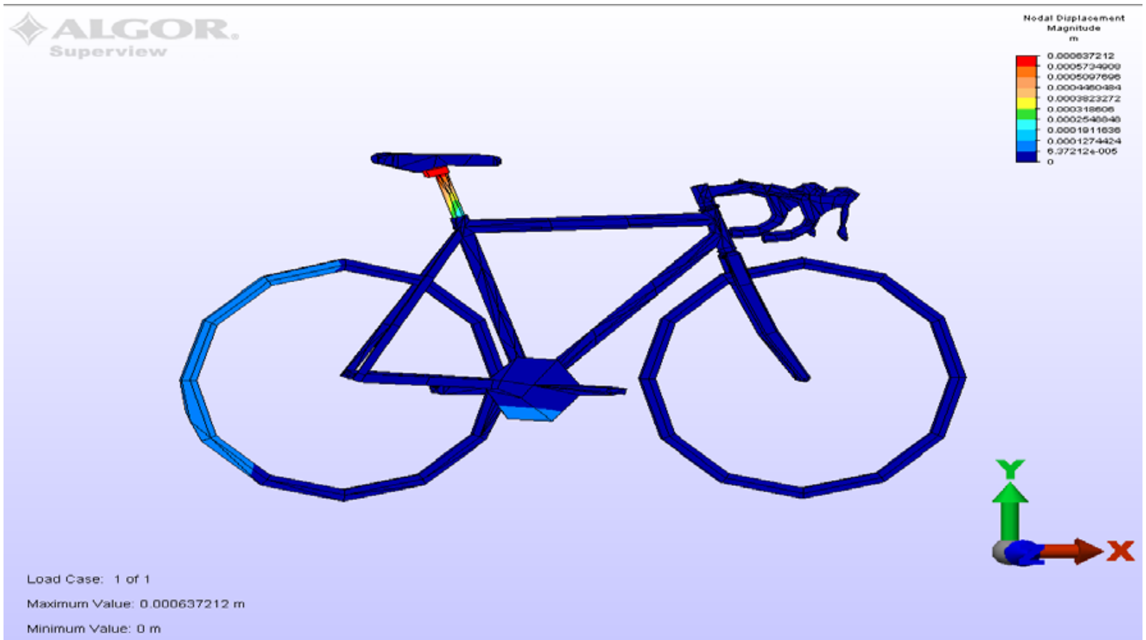



**Figure 4.1** Displacements for 50kg

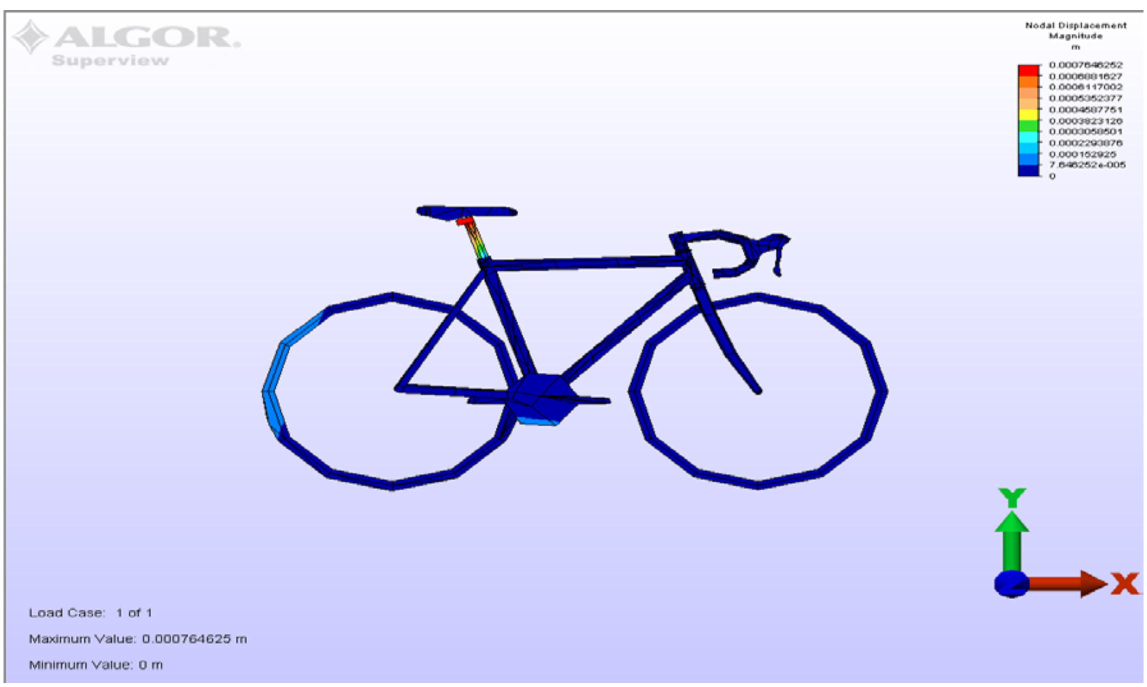



**Figure 4.2** Displacements for 60kg

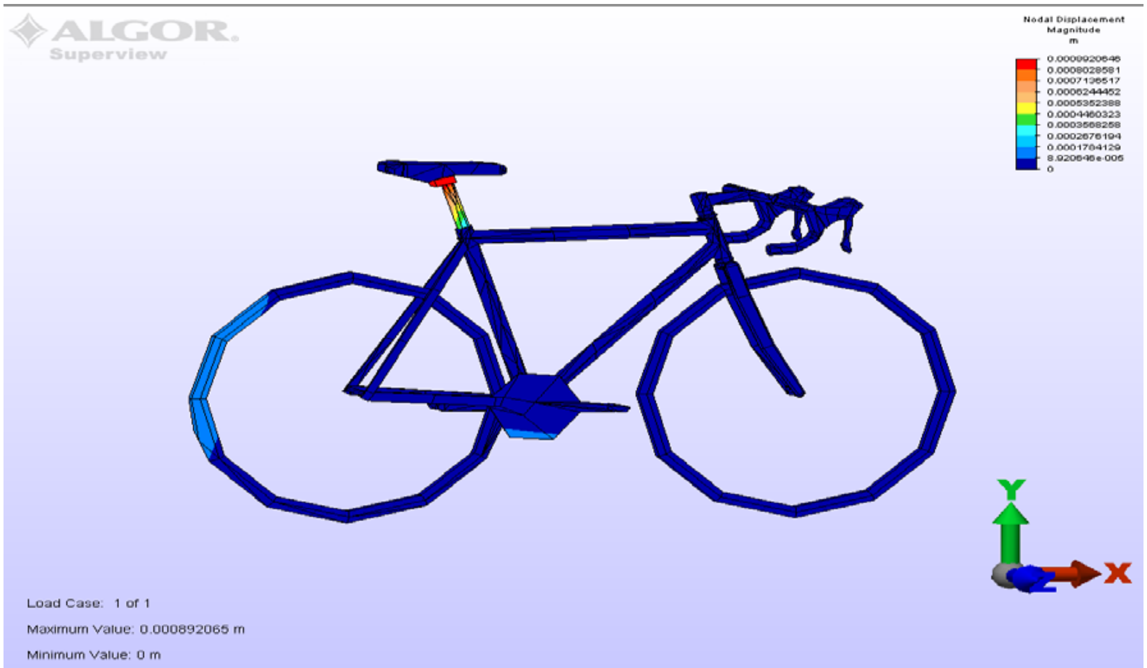



**Figure 4.3** Displacements for 70kg

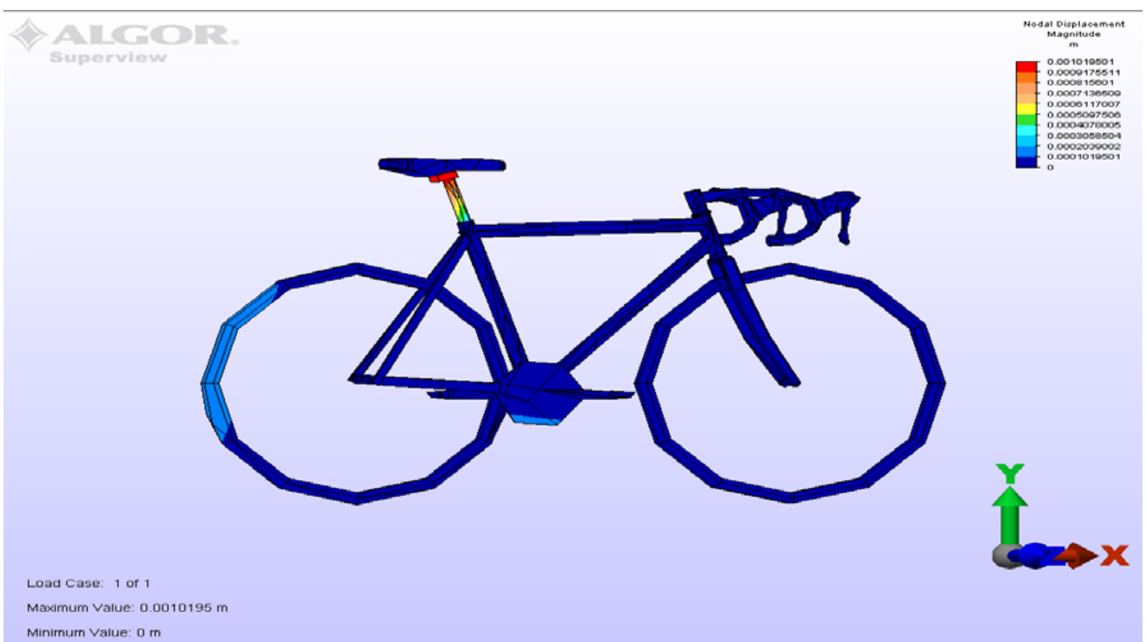



**Figure 4.4** Displacements for 80kg

## 4.6 RESULTS FOR STRESS

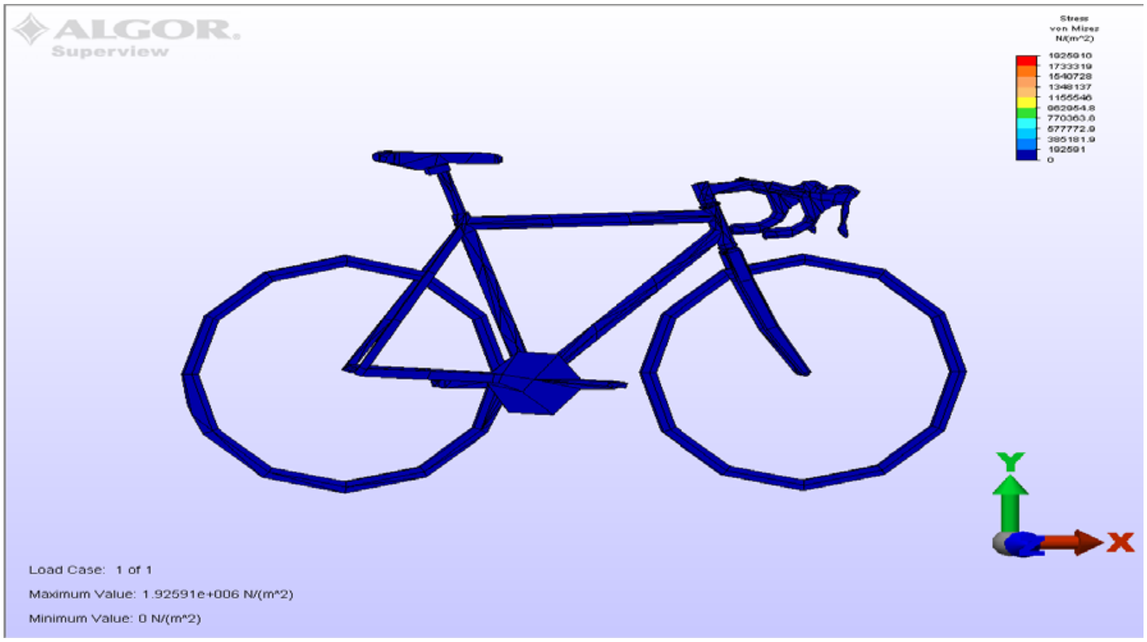



**Figure 4.5** Stresses for 50kg

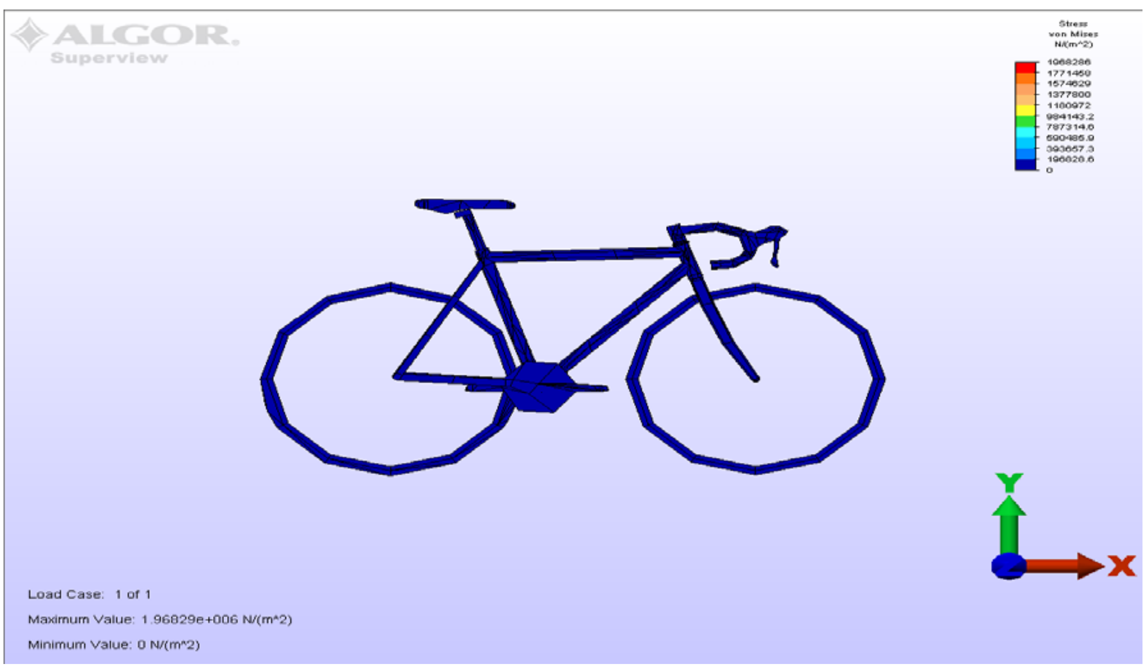



**Figure 4.6** Stresses for 60kg

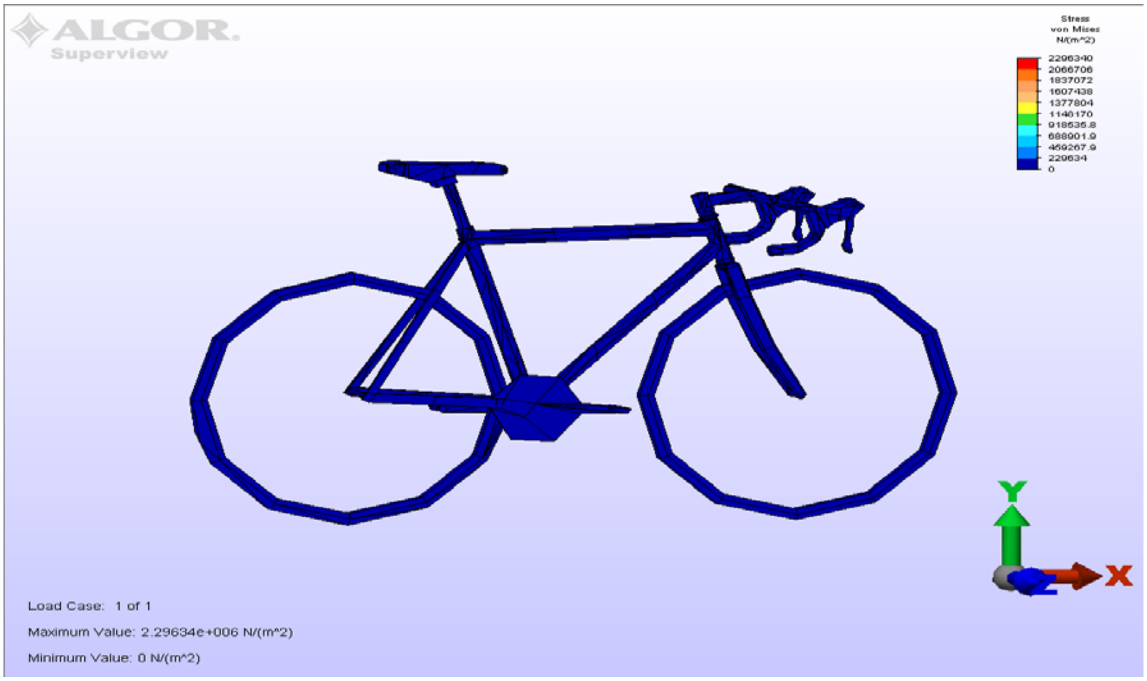



**Figure 4.7** Stresses for 70kg

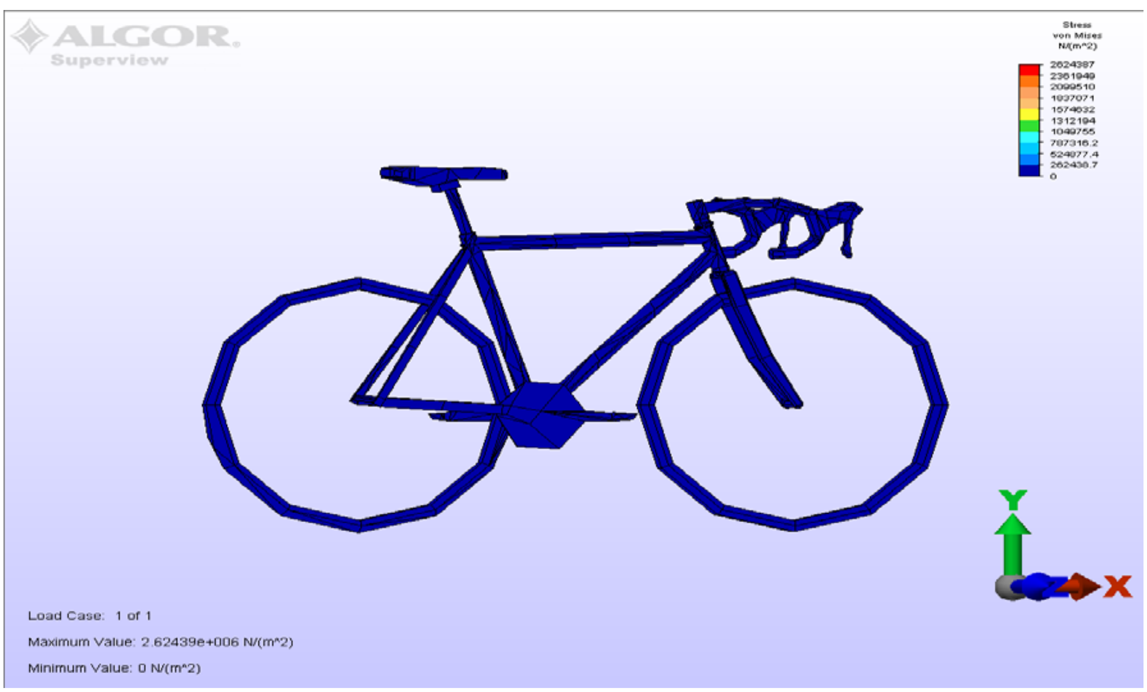



**Figure 4.8** Stresses for 80 kg

## 4.7 RESULTS FOR STRAIN

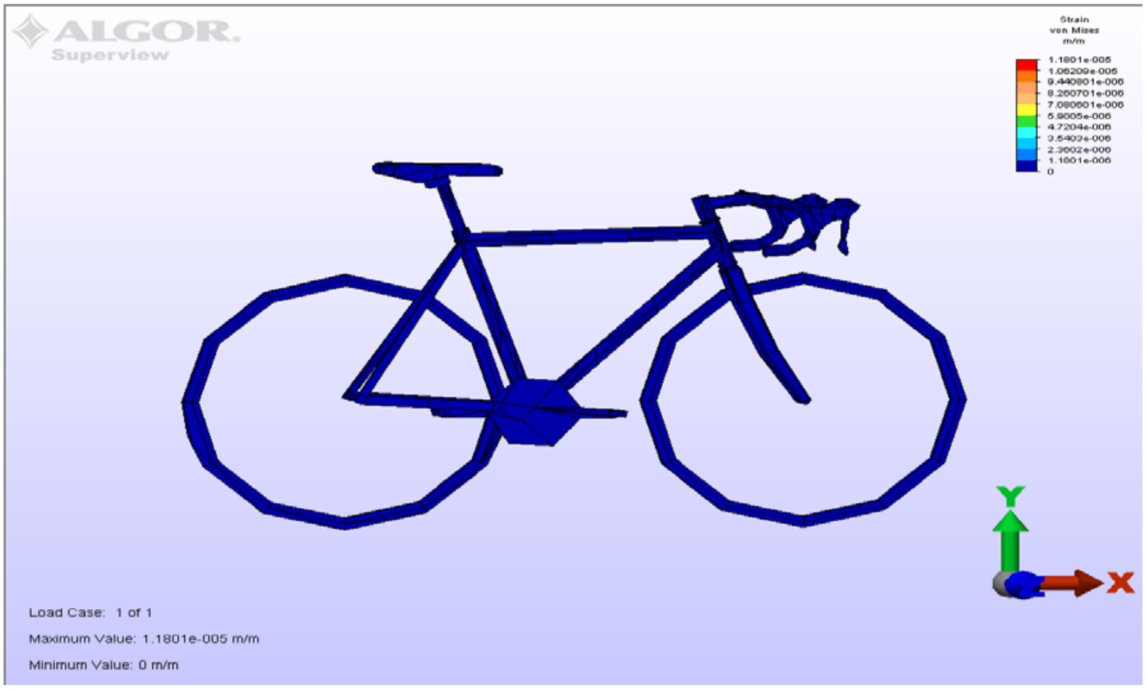



**Figure 4.9** Strains for 50kg


**Figure 4.10** Strains for 60kg

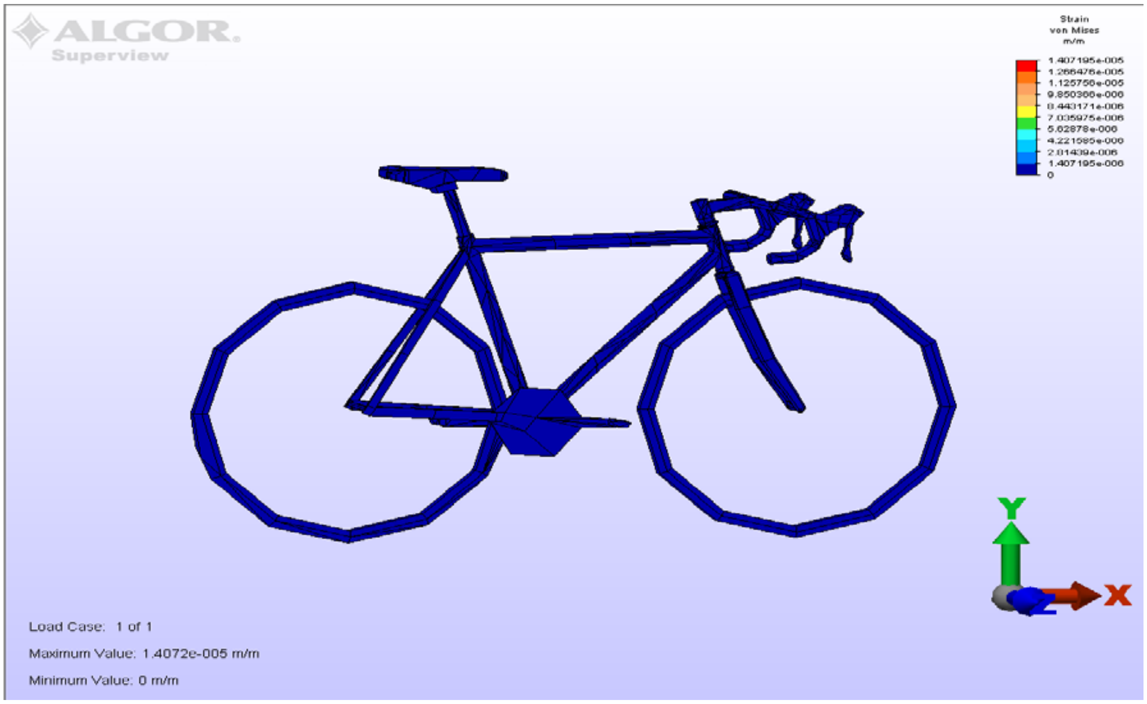



**Figure 4.11** Strains for 70kg

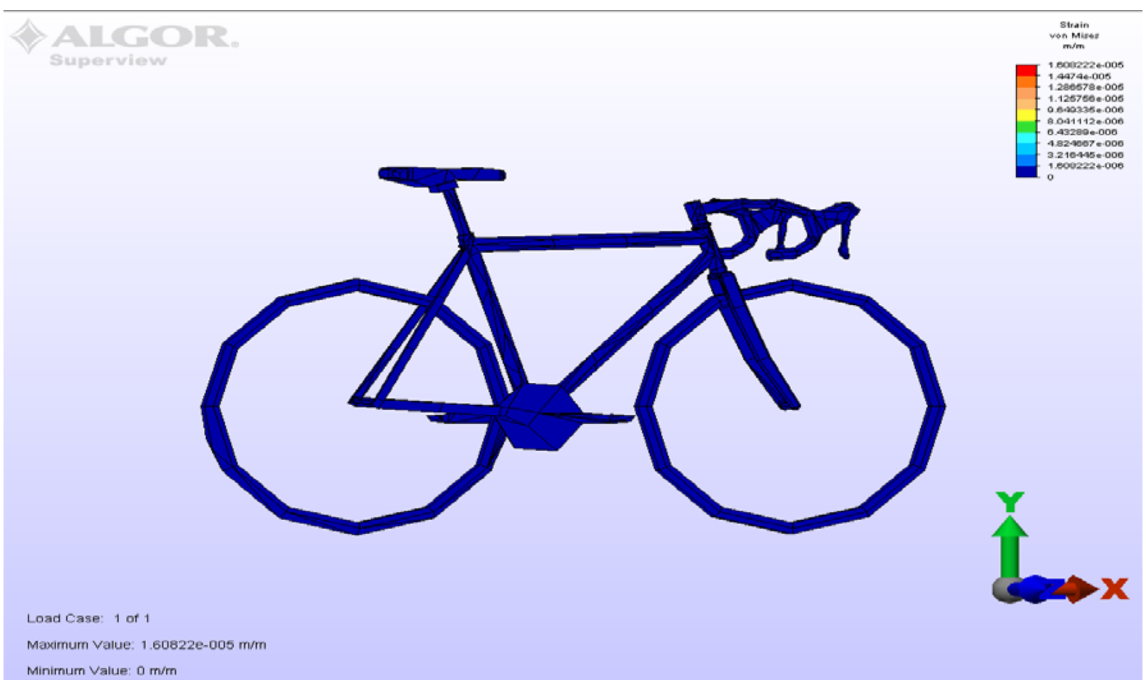



**Figure 4.12** Strains for 80kg

## 4.5 RESULTS AND DISCUSSION

The analysis for the new racing bicycle frame that was design in this project will show the critical point on the design and the maximum value for the displacement. This analysis was use Stainless Steel AISI (446) as the material that already in the Algor software. These analyses also generate a graphs. The graph is show the human weight versus maximum value of displacement which is shown in Figure 4.5.

### 4.5.1 Results in table

| Human weight (kg) | Displacement (m) | Stress 1.0xe$^{6}$(N/m$^{2}$) | Strain 1.0xe$^{-5}$(m/m) |
|---|---|---|---|
| 50 | 0.000637212 | 1.92591 | 1.1801 |
| 60 | 0.000764625 | 1.96829 | 1.20616 |
| 70 | 0.000892065 | 2.29634 | 1.4072 |
| 80 | 0.0010195 | 2.62439 | 1.60822 |

**Table 4.3** Analysis result

### 4.5.2 Graph

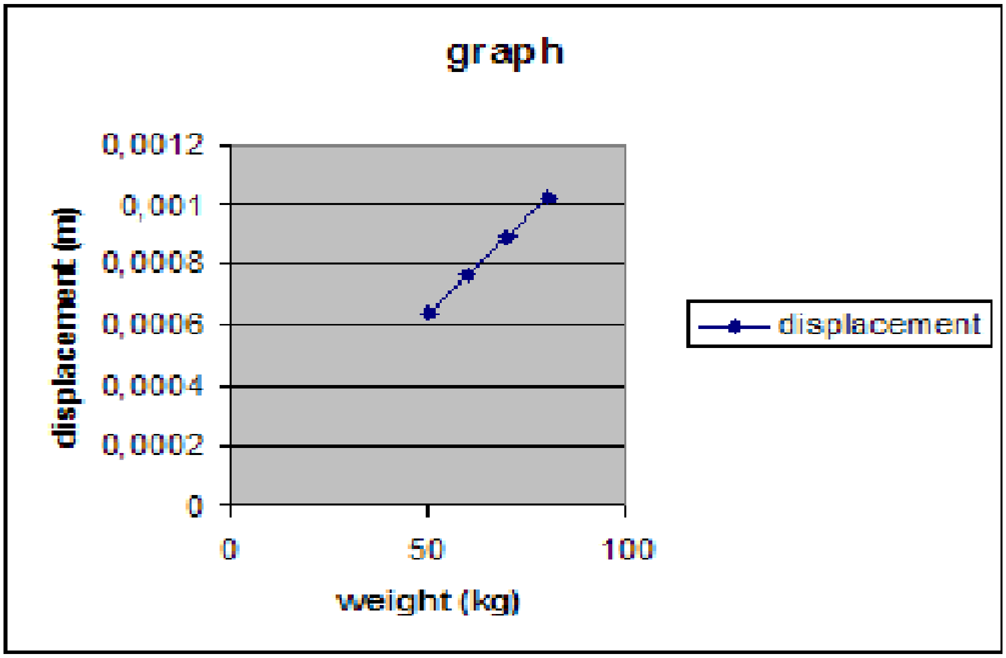



**Figure 4.5** Graph human weights versus displacement

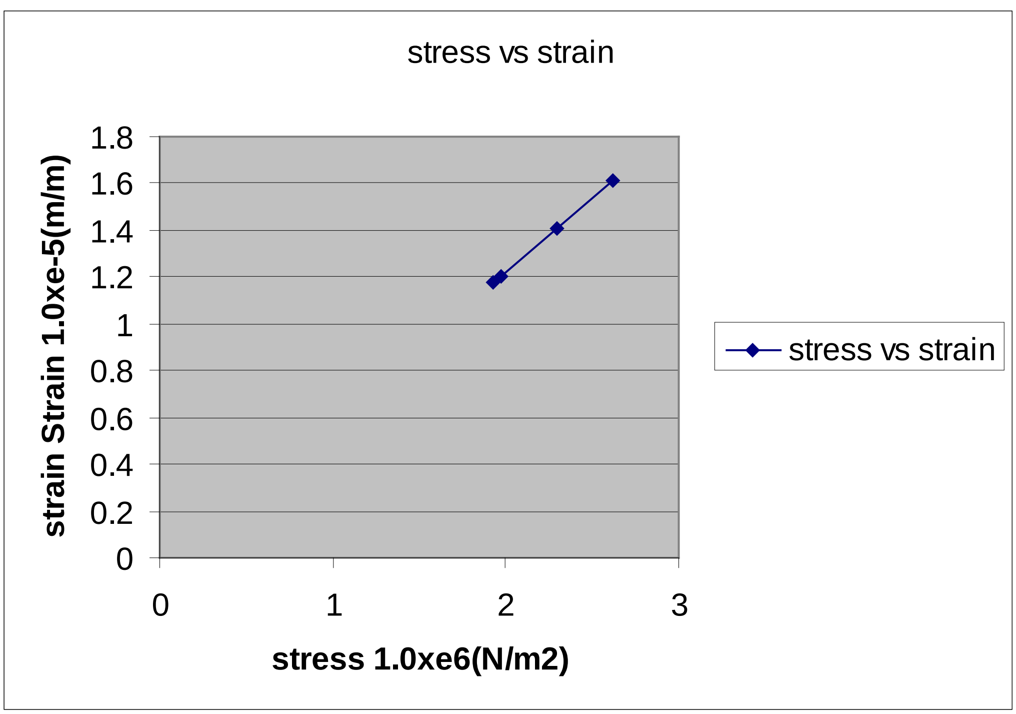



**Figure 4.6** Graph stress versus strain

### 4.5.3 Discussion

From the analysis result we can see that the critical point on the design is situated at bottom of the seat at the seat adjustable lock. We can see from the Algor result that the critical point shown in red colour. So, the design should be more consideration at the critical part there.

From the human weights versus displacement graph (Figure 4.5), we can see that the human weight is proportional to the displacement. If we increase the value of weight the displacement also will increase.

For the stress versus strain graph (Figure 4.6), it’s shown that the stress value proportional to the strain value.

# CHAPTER 5

# CONCLUSION

## 5.1 INTRODUCTION

This sub-topic will conclude the result was obtained from the analysis and also give the recommendation for this thesis. In this chapter, every suggestion that have been made will be elaborate in detail.

In previous chapter, analysis using different value of human weight for the new racing bicycle frame obtained value for displacement, stress and strain. From the result was successfully told this analysis is successfully done.

## 5.2 CONCLUSION

In this report, a new racing bicycle frame was analyzed to see the critical part on the design. The analysis showed us the critical part on the design which is at the bottom of the seat at the seat adjustable lock. The value of human weight that applied to the design which is between 50kg to 80kg was successfully analyzed using Algor software. The analysis also showed the value of displacement, stress and strain that we can see detail in the graph shown before.

Actually this project objective was achieved which is to design a new racing bicycle and analyze it. From the result that get from this project help us to improve the design for the next research hopefully.

## 5.3 RECOMMENDATION

For future planning, project like this maybe must study more detail on how to design a new racing bicycle frame. Maybe there are some other procedures that must be considered to make sure that we will get a best design.

For this project, the design must be improved at the critical point which is at the seat adjustable lock bottom of the seat. For the other part, it was no problem after analyze. But, it also can be improve for more effectiveness.

We also can analyze the design using different material to see the result and can compare to the other material. From that, we can choose the best material for our design.

The design also must analyze without error. We must make sure that there is no error when simulation. If there is error when simulation, the result that we will get is not accurate.

Lastly, maybe we can design a new racing bicycle that was different shape compare to the already design in market today. Maybe we can design a frame that did not follow the commonly most use frame which is diamond frame. Maybe we can analyze a circle frame.

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