**DEVELOPMENT OF A NEW BEAM SYSTEM BASED ON**

**THE PRE-STRESSING CONCEPT OF BICYCLE WHEEL**

by

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17509

Final Report submitted in partial fulfillment of the requirements for

Bachelor of Engineering (HONS) Civil Engineering

FYP II Sept 2016

Universiti Teknologi PETRONAS

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CERTIFICATION OF APPROVAL

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A project dissertation submitted to the

Civil Engineering Programme

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In partial fulfilment of the requirement for the

BACHELOR OF ENGINEERING (Hons)

(CIVIL)

Approved by,

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TRONOH, PERAK

SEPT 2016

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

**\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**

EVON GOH EU EARN

**ABSTRACT**

Lightweight beam is always an interest in construction field which provides adequate bending capacity as conventional beam. Innovation on the web to improvise the beam to lighten the self-weight and provide extra space for services are in progress. For the first time, bicycle wheel is introduced to design as web. The bicycle wheel is an efficient structural element which able to resist vertical loads, while withstanding traction, braking, and side loads. Therefore, the idea of integrating the pre-stressing of bicycle wheel with structural I-beam to develop a new beam system. The new beam model integrated with bicycle rim is produced by using a commercial Finite Element software, ANSYS. The research focused on testing bending moment, stress, strain and deformation of the new beam. The study shows the new beam is tested in load carrying capacity and proof the similar behaviour of stress intensity and deformation as ordinary I-beam. In conclusion, the research managed to provide better insight for future research in engineering application. The recommendations for this study is to incorporate different parameters such as spoke length, spoke material, spoke diameter and the arrangement of the rim which will affect the performance of the new beam system.

**ACKNOWLEDGEMENT**

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Finally, I strongly believe that teamwork has played a major role in completing this research project where the help from friends contributed a lot in this research project. Thus, I am grateful for the guidance and assistance that I have received throughout this 8-month research project in the Department of Civil and Environmental Engineering, Universiti Teknologi PETRONAS.

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# **CHAPTER 1**

# **INTRODUCTION**

* 1. **BACKGROUND**

Since the 1940s, structural engineers had tried different way to lower the cost of steel structure. However, the high strength structural steel cannot be utilized to the best because of the limitation on maximum allowable deflection. Recently, castellated and cellular beams have been used as new method to increase the stiffness of steel member without increase the self-weight of the steel required. [2]

Different studies of various shape and opening size at the web of beam have been proposed to reduce the beam weight while increasing the shear and moment capacity.

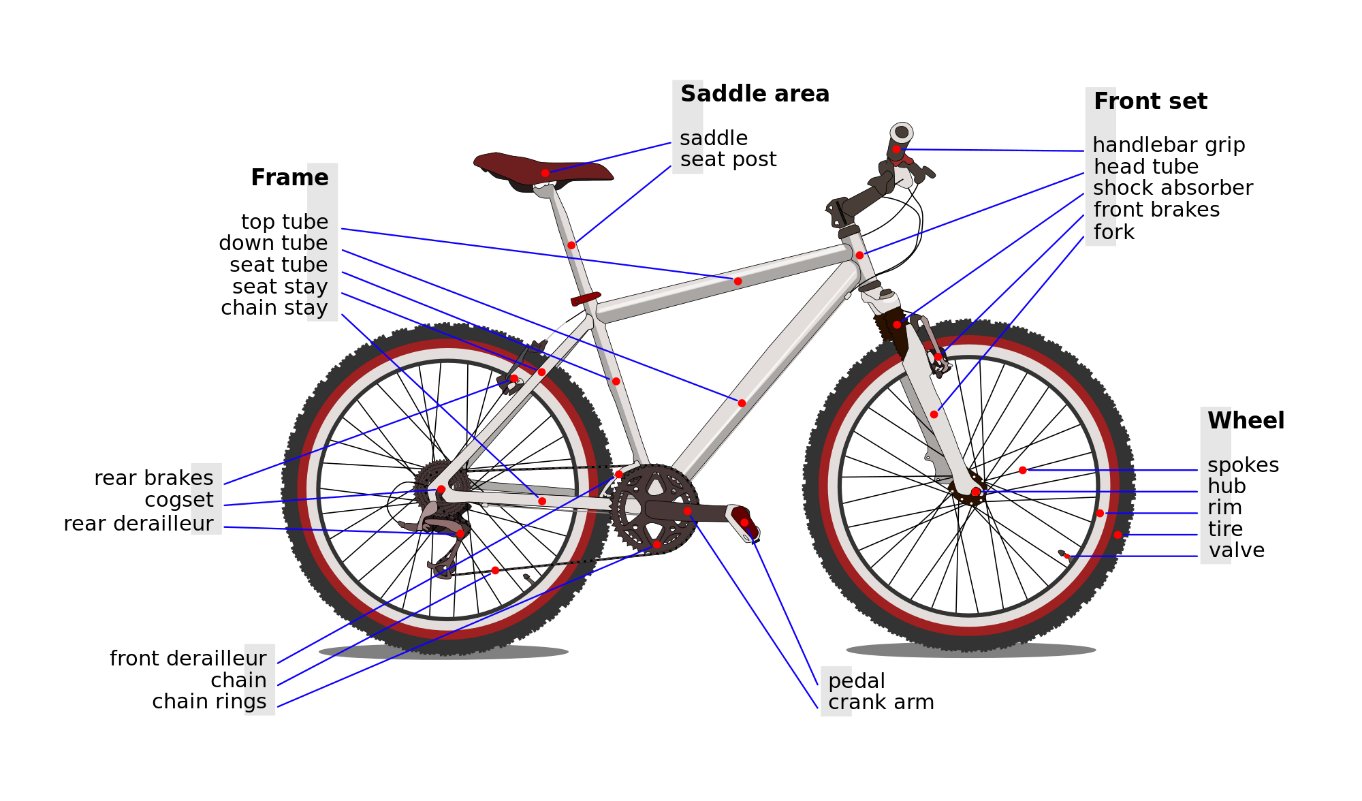


Figure 1 Name of Bicycle Parts

Bicycle is one of the great invention that require a lot of precise engineering calculation. The frame of a bicycle is light weight and used less material but can withstand high load. The bicycle wheel is known as the most efficient structural element use [2].

During old time, to replace the wooden wheel, wire spokes had been introduced. However, wire spokes cannot be placed directly as it will cause buckling after carry load in compression and then wire-spoke bicycle wheel was introduced more than a century ago to replace it. Therefore, to prevent buckling, wires must be pre-tensioned. A light weight bicycle come from tensioning the wires made these wheels possible. With pre-tensioned properties, a wire can support compression until they become slack by reducing the tension in wire. Wire spokes can reduced weight but improved durability. A modern wire wheels can carry a hundred times of the wheel own weight. [3]

When a spoke is assembled in to a wheel set, it will be in the pre-stressed mode which in elongated state when unloaded. When load is applied, it get compressed and the elongation decreases. However, the original elongation provided to the spokes while installing is higher than the decrease in elongation. Therefore, it can be said that a spoke is always in tensed state.

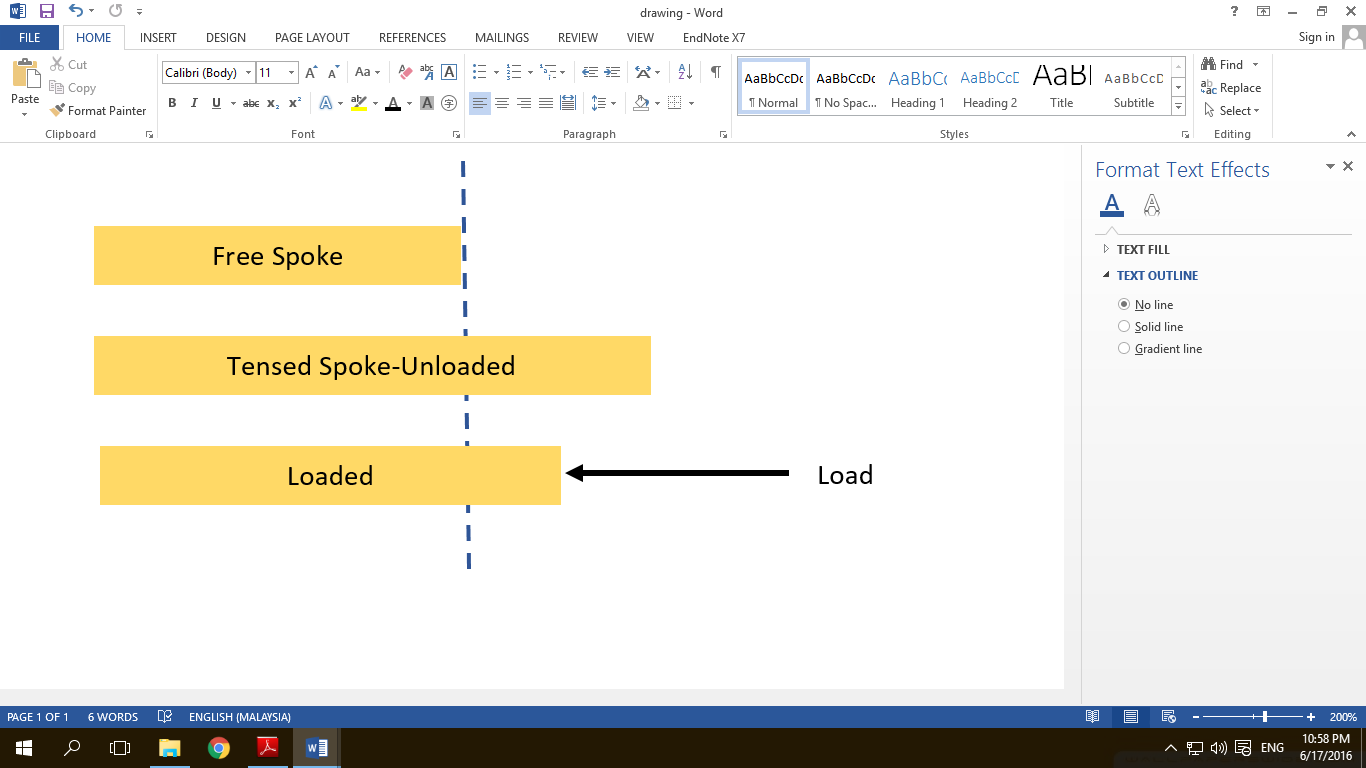


Figure 2 Illustration of Free Spoke, Unloaded Tensed Spoke and Loaded Tensed Spoke.

Spokes on a bicycle do not support the weight as it goes down from hub to bottom of the wheel. The wheel support the weight by pull up the hub to the top of wheel. This is also one of the reason that can make a wheel so flexible as the spoke can be consider to work like a rope.

* 1. **PROBLEM STATEMENT**

Light weight material Typical I-beam has high self-weight that will contribute to the weight of the building.

Recently, the fluctuation of structural steel price cause increase of construction cost as steel is one of the important material in construction. Because of that, it increases the price of I-beam.

There is limited literature study on steel beam with proposed novel web. This study helps to widen the limitation for the design of beam web.

* 1. **OBJECTIVE**

The objectives of this research are as followed:

* To investigate the potential of non-standard web shape such as bicycle rim and verify against existing work using ANSYS.
* To carry out parametric study on the effect of spoke and rim sizing to the behaviour of the new beam
* To integrate the pre-stressing concept of bicycle wheel and develop a new beam system.
  1. **SCOPE OF STUDY**

An analysis was coordinated in order to integrate a bicycle rim as a replacement module for the I-beam’s ordinary web system. The study was done using a bicycle rim with a 16 spoke – rim in a radial arrangement. The focus of the study was the deflection and deformation of the I-Beam when the replacement (Bicycle Rim) is compared with the ordinary web based system. The outcome was then compared in terms of their effectiveness in handling both deflection and deformation.

Having two different parts, the first part basically involved understanding the pre-stress concept regarding the spokes on a bicycle wheel and the beam connection of a support. The second part on the other hand involves simulating the model using the ANSYS software. Several models were drafted and produced in order to have a comprehensive comparison between the two concepts.

# **CHAPTER 2**

# **LITERATURE REVIEW**

2.1 Steel Beam

Steel beam can be used as column, beam or beam-column. Different between eccentrically loaded column and beam-column is that eccentrically loaded column is where axial pressure is the primary effect while bending as unavoidable imperfection is the secondary, while beam column is where axial pressure is the primary effect and bending is intentionally applied. Steel beam come in various shape such as I beam, O beam, bar, structural tubing, angled, half round and more. This study will use the principle of I beam while replace the web with bicycle wheel.

As the concept of new beam system, there are a few parts of the beam can be resemble into few concepts in finite element method. For the flanges, it will be using plate (see below) method, the wheel rim will resemble ring and the spokes is similar to catenary.

2.2 Bicycle Rim

Despite the evolution in design and the use of modern materials, the basic structure of the modern spoked wheel has remained constant. The basic structure consists of three major components which are a hub that houses the bearings and the axle, pre-tensioned spokes that join the hub to the rim; and, a rim made of rolled or extruded material.

Modern bicycle wheels are now built with a range of spoke patterns radial. The pattern not only change the appearance of the wheel but affect the strength, torque resistance, flexibility, air resistance, weight. For Radial spoke patterns are more likely to be used on front wheels since they do not experience significant torque loading unless hub or disk brakes are used.

2.3 Element

2.3.1 Plate Element

Plank is most common item. A beam (Figure 3) shows the force resultants acting on a two-dimensional plate element and (Figure 4) shows moment resultants acting on the two-dimensional plate element [2]. Each plan of the plank will have 3 nodes. Loads on the plate in the x-, y-, and z -directions are denoted by px, py, and pz in Figure 3. These are the external forces acting on the plate at a given point. External loads can be applied as body forces, such as gravity, and they can be applied as surface tractions, in which case they correspond to the stresses. The moment resultants given will have the units of moment per unit length, and act in the directions shown in Figure 4. Mx and My are bending moment resultants. The directions of these moments are determined so the right-hand vector representation is as seen in Figure 4. Thus the vector Mx is in the y-direction, and My is in the negative x-direction.

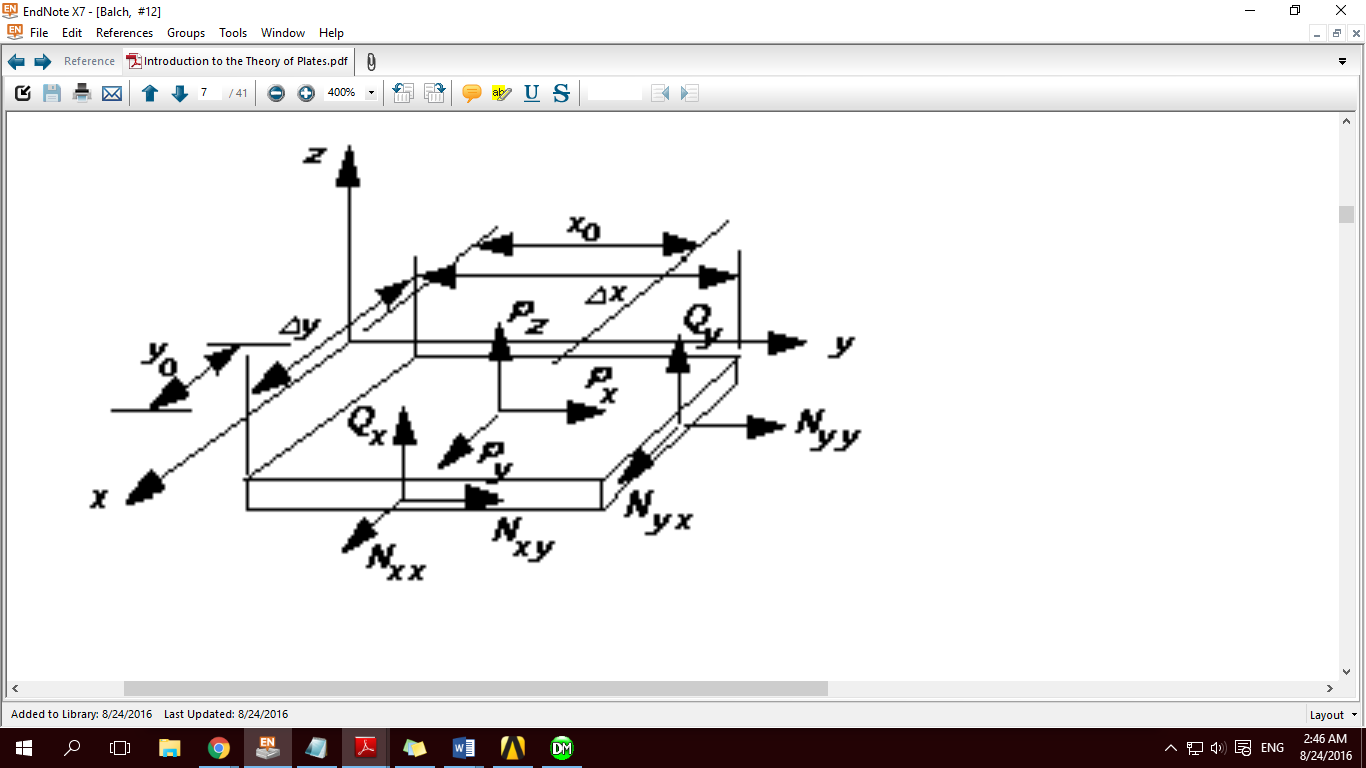


Figure 3 Force resultants acting on a two-dimensional plate element

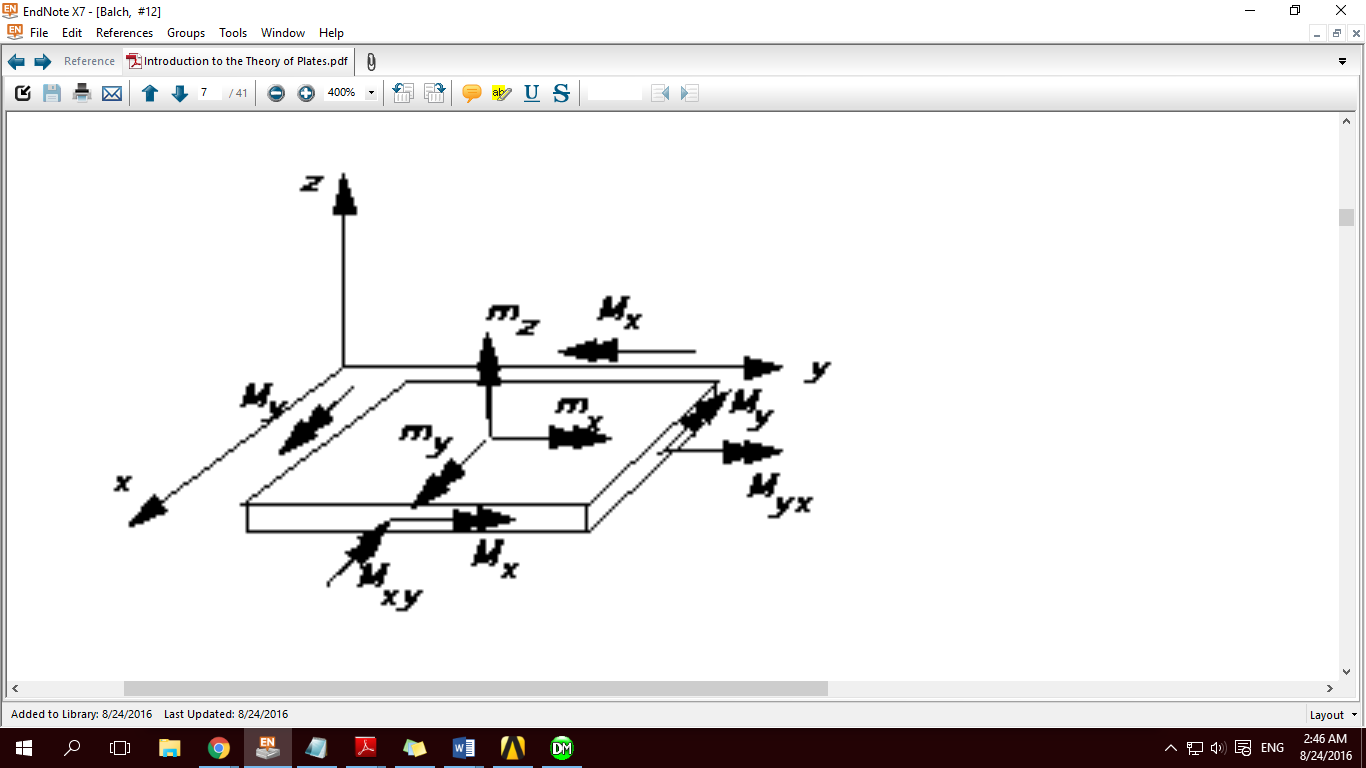
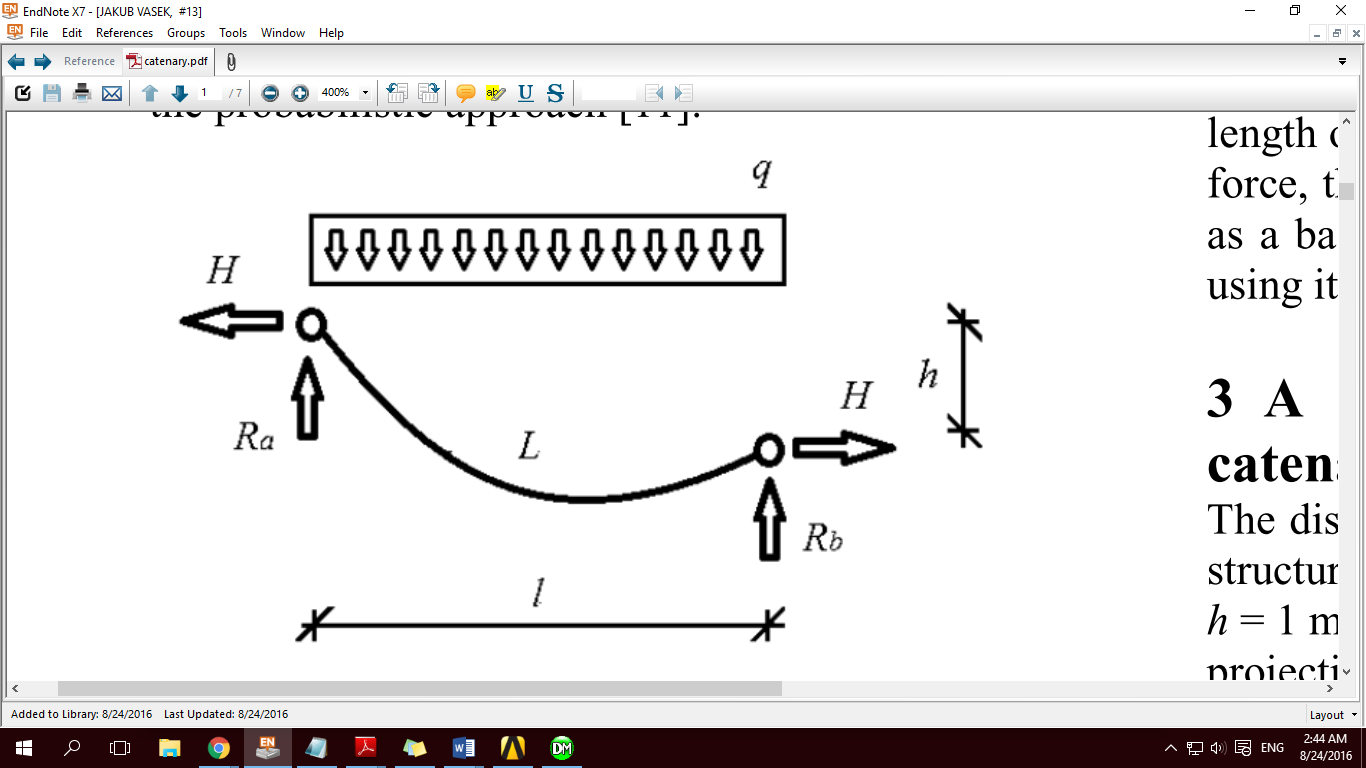


Figure 4 Moment resultants acting on the two-dimensional plate element

2.3.2 Catenary Element

Catenaries are commonly used analysis methods for cable structures. The visible characteristic is that it will slack in compression. The catenary element is very useful in tension mode. The cable which is suspended in two joints and loaded with a continuous load applied onto the horizontal projection is referred to as a parabolic catenary, (Figure 5). Because of a very low bending stiffness, the load-carrying cable is considered in calculations to be an element which does not bear bending moments. The only internal force which arises in the structure is tensile force. All geometric and static quantities are expressed by means of horizontal reaction [6].



*Figure 5 Parabolic Catenary*

2.3.3 Ring Element

Ring element is usually used for item such as rim, cylindrical object. Ring can be said to have unlimited symmetry, therefore, by doing a part of the structure, we can manage to obtain the same information, constrained by appropriate boundary conditions, which results in an appreciable savings in computer time. [5]

The boundary conditions on the segment are chosen so as to be compatible with the deflections experienced by the complete structure in each mode shape desired. Hence, any modes whose deflections are not compatible with a given set of boundary conditions cannot be obtained from that set. It is obvious from the statements above that symmetry methods are applicable only in cases where the nature of the mode shapes has been predetermined.

2.4 Material

There are different parts in the model that need to be specific define in different material. For the constant I-beam and model flange, structural steel will be used for both item. For this research, structural steel of grade S275JR will be used as it is the common industrial grade in Malaysia. Alloy aluminum is used for the bicycle rim in the beam model. Alloy aluminum is a material that slightly weaker than steel but has much lower density. It will cause the whole structure to be lighter than a pure steel structure. While the spokes of bicycle will be using stainless steels.

2.4.1 Structural Steel S275

Structural Steel grade S275 is usually used for most civil construction to general engineering. Table 1 and Table 2 show the chemical composition and mechanical properties of S275 respectively. There are three other grade under Grade S275, which is S235JR, S235J0 and S235J2 steel grade. They are the common carbon steel place. Based on Table 1, The structural steel has minimum yield point of 275 N/mm2 and tensile strength at the range of 410 N/mm2 to 560 N/mm2*.* Structural steel S275 has the highest portion of magnesium in it (Table 2).

*Table 1 The mechanical properties of S275JR [1]*

|  |  |  |  |
| --- | --- | --- | --- |
| Grade | Yield Point N/mm2(min.) | Tensile Strength N/mm2 | Elongation % (min.) |
| S275JR | 265 | 410-560 | 23 |

Table 2 The chemical compositions of S275JR [1]

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Grade | Carbon | Magnesium | Phosphorus | Sulphur | Nickel | Copper |
| S275JR | 0.21 max. | 1.50 max. | 0.035 max. | 0.035 max. | 0.012 max. | 0.55 max. |

2.4.2 Alloy Aluminum 6061-T6

6061 alloy aluminum is one of the most common alloy of aluminum. It got the strength of medium to high with good toughness. Table 3 and Table 4 show the chemical composition and mechanical properties of Alloy Aluminium 6061-T6 respectively. Grade 6061 consist of few grade with different temper such as T1, T4, T6. The ultimate tensile strength increases with each temper. T6 has the highest ultimate tensile strength that can reach 310 MPa. Grade 6061 is commonly used for aluminum cans packaging, tactical flashlights, automotive parts. Grade 6061-T6 is highly used in fishing reels, helicopters parts and bicycle rim due to the high strength and low weight.

Table 3 The mechanical properties of Alloy Aluminum 6061

|  |  |  |  |
| --- | --- | --- | --- |
| Grade | Hardness (Brinell) | Tensile Strength N/mm2 | Elongation % (min.) |
| 6061-T6 | 97 | 310 | 13 |

Table 4 The chemical compositions of Aluminum Alloy 6061

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Grade | Magnesium | Silicon | Iron | Copper | Zinc |
| 6061 | 0.8-1.2 | 0.4-0.8 | 0.7 max. | 0.15-0.40 | 0.25 max |
|  | Titanium | Manganese | Chromium | Other |  |
|  | 0.15 max | 0.15 max | 0.04-0.35 | 0.05 |  |

2.4.3 Stainless Steel SS304

Table 5 and Table 6 show the chemical composition and mechanical properties of SS304 respectively. Stainless steel is a form of steel containing a minimum of 18% chromium content that gives resistance to tarnishing and rust. There are three grades of type 304 stainless steel which are SS304, SS304L and SS304H. Grade SS304L has the special properties of lower carbon which does not need post weld annealing. On the other hand, Grade SS304H is highly applicable at elevated temperature because it has higher carbon.

Table 5 The mechanical properties of SS304

|  |  |  |  |
| --- | --- | --- | --- |
| Grade | Hardness (Brinell) | Tensile Strength N/mm2 | Elongation % (min.) |
| SS304 | 170 | 600 | 60 |

Table 6 The chemical properties of SS304

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Grade | Manganese | Phosphorus | Sulphur | Silica | Nickel | Chromium |
| SS304 | 2.0 max. | 0.045 max. | 0.030 max. | 1.0 max. | 8.0-12.0 | 18.0-20.0 |

# **CHAPTER 3**

# **METHOLOGY**

## **3.1 RESEARCH METHOLOGY**

The research methodology can be divided into two main parts;

1) Supervisor Consultation.

Supervisor is one of the main sources of reference for the project especially when there is a problem that requires expert clarification. Consultation with supervisor is also required during understanding the equation and principles related to the element in the beam set and also problems regarding finite element.

2) Developing ANSYS model, meshing and applying load

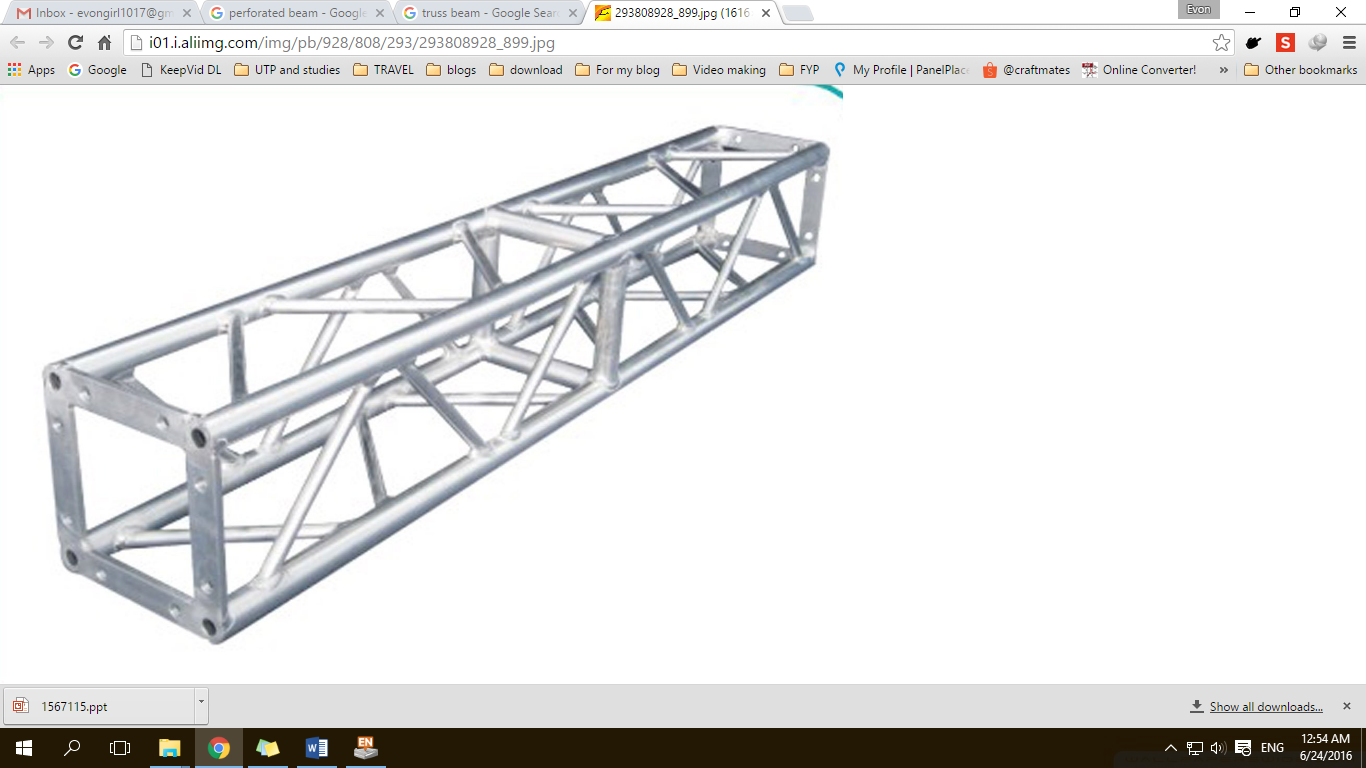
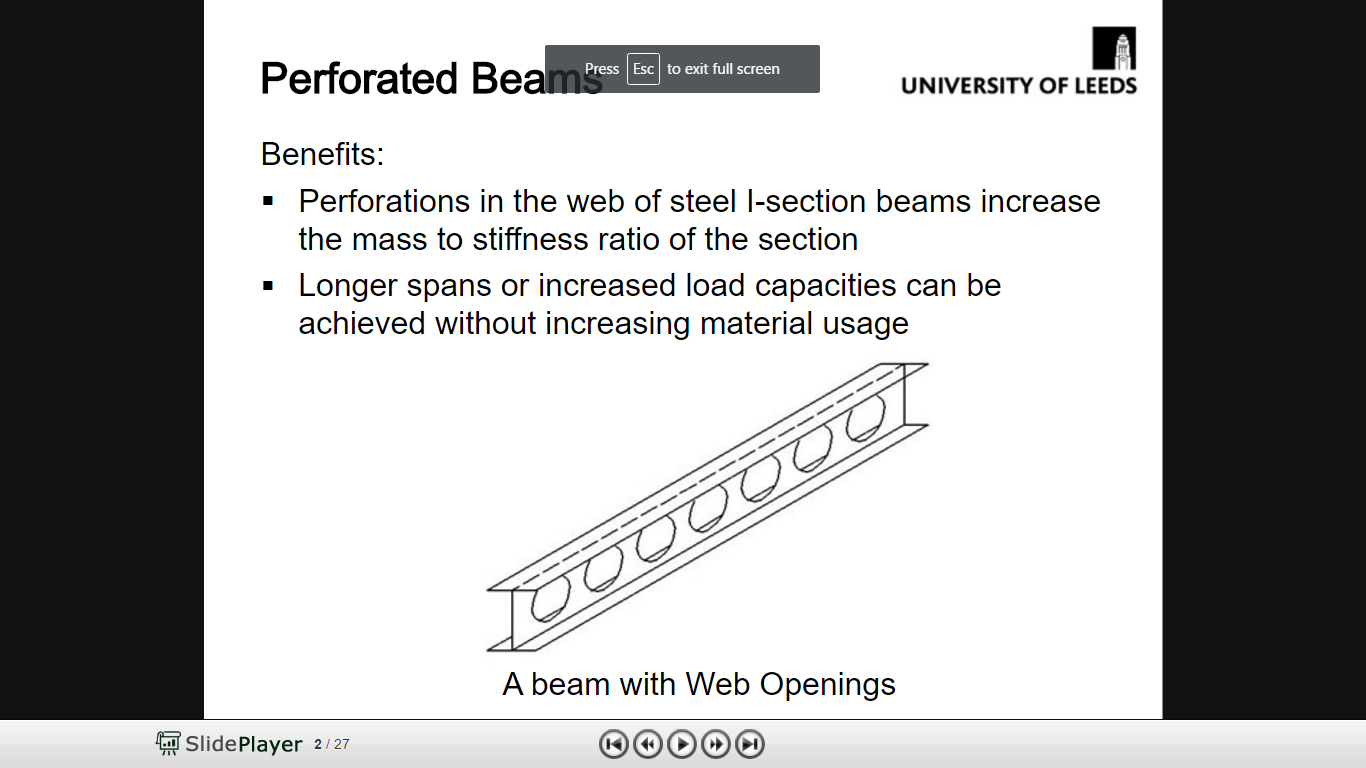
To validate the experimental result, simulation of the experiment needs to be performed in ANSYS Workbench. The simulation starts with modeling of a model, which has meet all the requirement. Next, the models are meshed and lastly, the load is applied, in this case, force. The simulation is solved and the result is analyzed.

## **3.2 Project Work Flow**

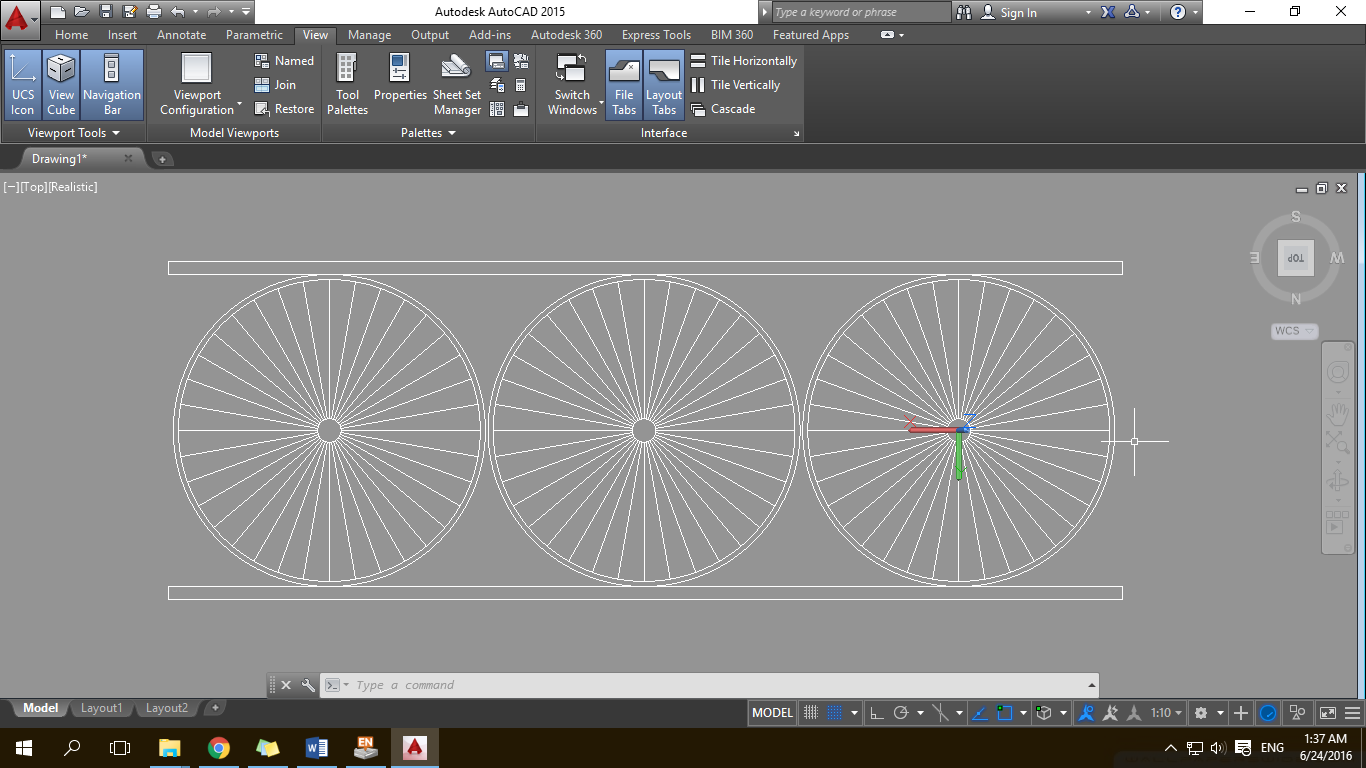
The research flow of this project is as shown in Figure 6. The research starts with the project title selection until the conclusion and recommendation. Once the topic is decided, extensive research on previous paper that is related to my topic was done in Literature Review section. Certain parameters have been looked for identifying the research gap before conducting the experiment in order to improve the previous research. By relating to this topic, the parameters considering this study are the pre-stress properties and the overall properties of the beam.

At develop structure model stage, a model of beam integrate with bicycle rim will be produce by using ANSYS Workbench.

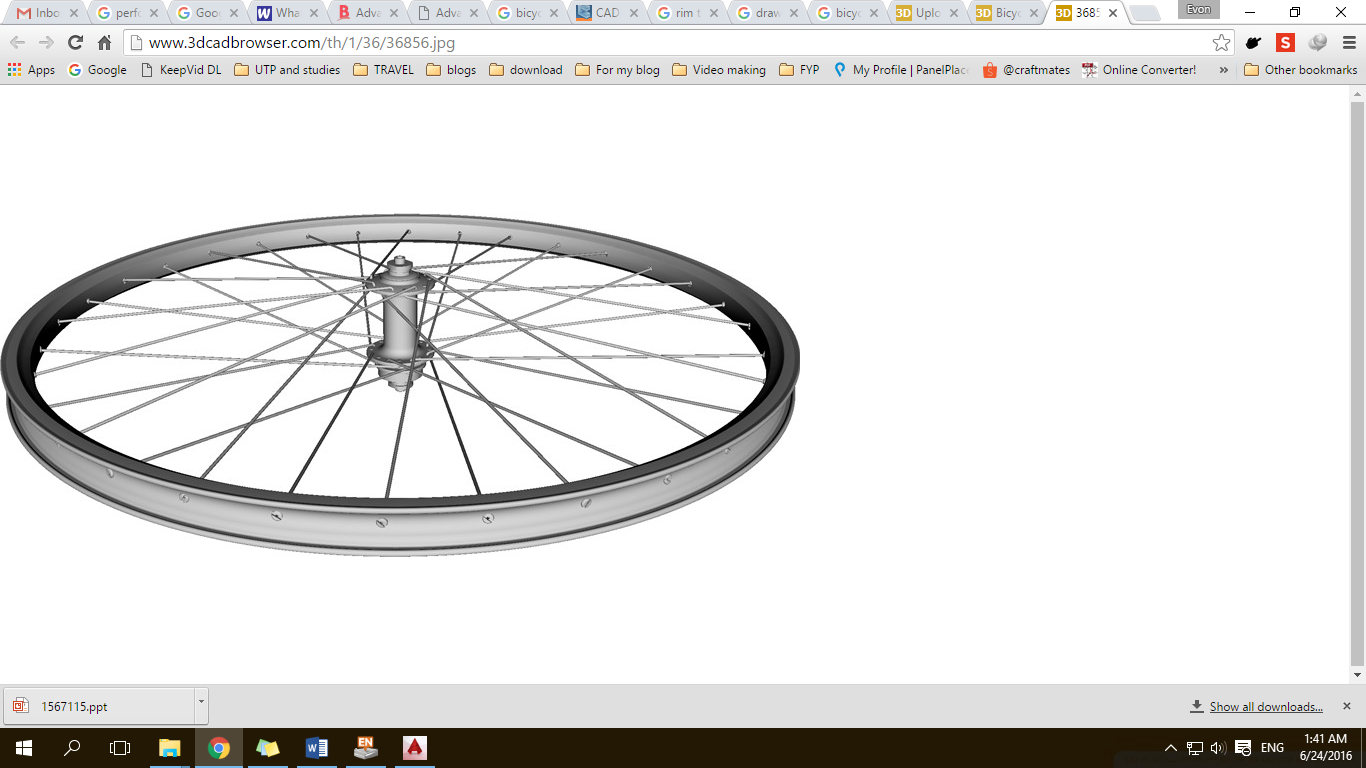
Figure 6 Research Flow of Project.



Perforated beam Truss beam



Beam system with pre-stressing concept of bicycle wheel

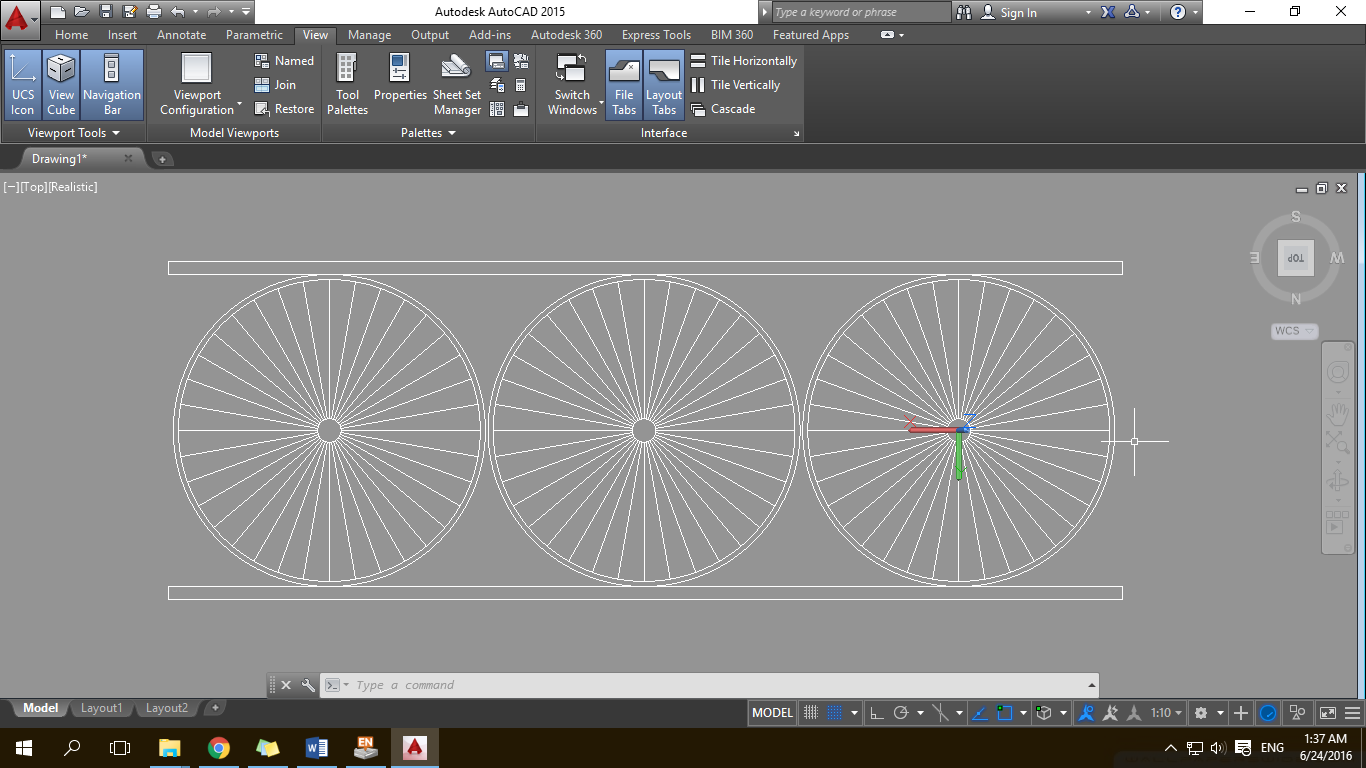
 

Steel beam Bicycle wheel

Figure 7 Concept evolution of Project.

Figure 7 shows that idea of the new beam concept came from the existing item such as perforated beam, truss beam, steel beam and bicycle wheel. Perforated beam and truss beam managed to show that the web of a beam is not necessary to have full material. It can be perforated to provide space for services and save material. A truss beam always properly designs to withstand the load with truss system. The idea of these items adds up to create a new system by using bicycle wheel will expect to have a good result.

When compression load applies on the flange, it will transfer the load to web. For the experiment, the web will be constructed of bicycle rim, refer to Figure 8. As mentioned about the properties of bicycle rim, the bicycle rim will accept the compression load by decrease the tension in the pre-tension spoke. The failure of the web will occur when the pre-tension spoke receive more compression than the tension in it and it became slack.



Tension

Compression

Figure 8 Load Distribution Illustration.

## **3.3 ANSYS MODELLING**

3.3.1 Define Material Properties

There are few material properties that need to be defined for the models. Each model is made up of SS304 steel as the parent metal and SS308L for the weld metal. There are 3 important parameters hat needs to be defined for each model, modulus of elasticity, Poisson ratio and density for both parent metal and weld area. The Table 7 shows the properties of the three materials.

Table 7 Properties of Structural Steel S275, Aluminium Alloy 6061, Stainless Steel SS304

|  |  |  |  |
| --- | --- | --- | --- |
| Material | Structural Steel S275 | Aluminum Alloy 6061 | Stainless Steel SS304 |
| Density (kgm-3) | 7860 | 2770 | 7750 |
| Young’s Modulus (MPa) | 200000 | 71000 | 193000 |
| Poisson’s ratio | 0.26 | 0.33 | 0.31 |
| Tensile strength (MPa) | 460 | 310 | 600 |

3.3.2 Boundary Condition

Both end of the beam will be fixed support, have zero displacement at all direction. Distributed force will be applied on the top of the beam to test the beam.

3.3.3 Modeling

Table 8 and Table 9 show the properties of I beam and the new bicycle beam. Both of the beams got the same flanges size and thickness of web. Figure 9 and Figure 10 show the model of I beam and the new bicycle beam.

Table 8 Dimension of I beam

|  |  |
| --- | --- |
| 610x305x238 UB | |
| Designation | Dimension (mm) |
| Depth of section | 635.8 |
| Width of section | 311.4 |
| Thickness of web | 18 |
| Thickness of flanges | 31.4 |
| Length of beam | 1819 |

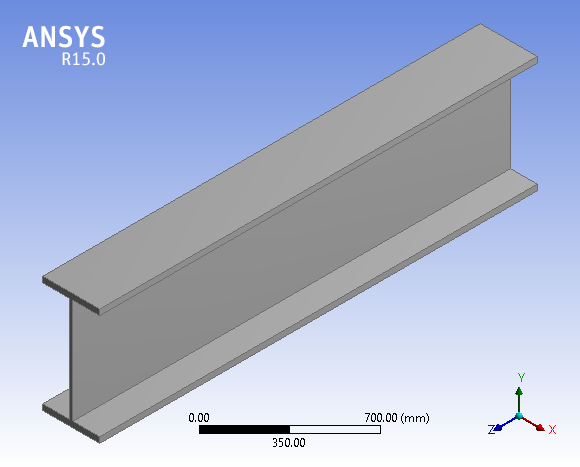


Figure 9 Model of Beam 610x305x238

Table 9 Dimension of Bicycle Rim Beam

|  |  |
| --- | --- |
| Bicycle rim beam | |
| Designation | Dimension (mm) |
| Depth of section | 635.8 |
| Width of section | 311.4 |
| Diameter of rim | 573 |
| Width of rim | 18 |
| Depth of rim | 20 |
| Diameter of spokes | 3 |
| Thickness of flanges | 31.4 |
| Length of beam | 1819 |

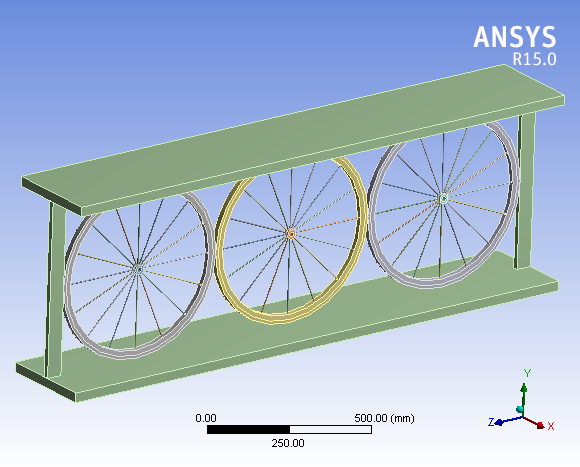


Figure 10 Model of New Bicycle Beam

3.3.4 Meshing

Meshing is performed in ANSYS to represent field variables such as displacement by polynomial function that produces a displacement field compatible with applied boundary conditions. The size of the mesh has significant effect of the final result of the simulation, thus the size of the mesh was kept constant for all models. During meshing, the type of material properties was defined for each volume. Figure 11 shows the meshing of Beam 610x305x238 while Figure 12 shows the meshing of Bicycle Beam. The I-Beam use meshing of 7.5mm that is similar with the verification work (See Chapter 4.1). For the meshing of bicycle beam, the auto mesh is used because the simulation will take too long due to the complicated structure.

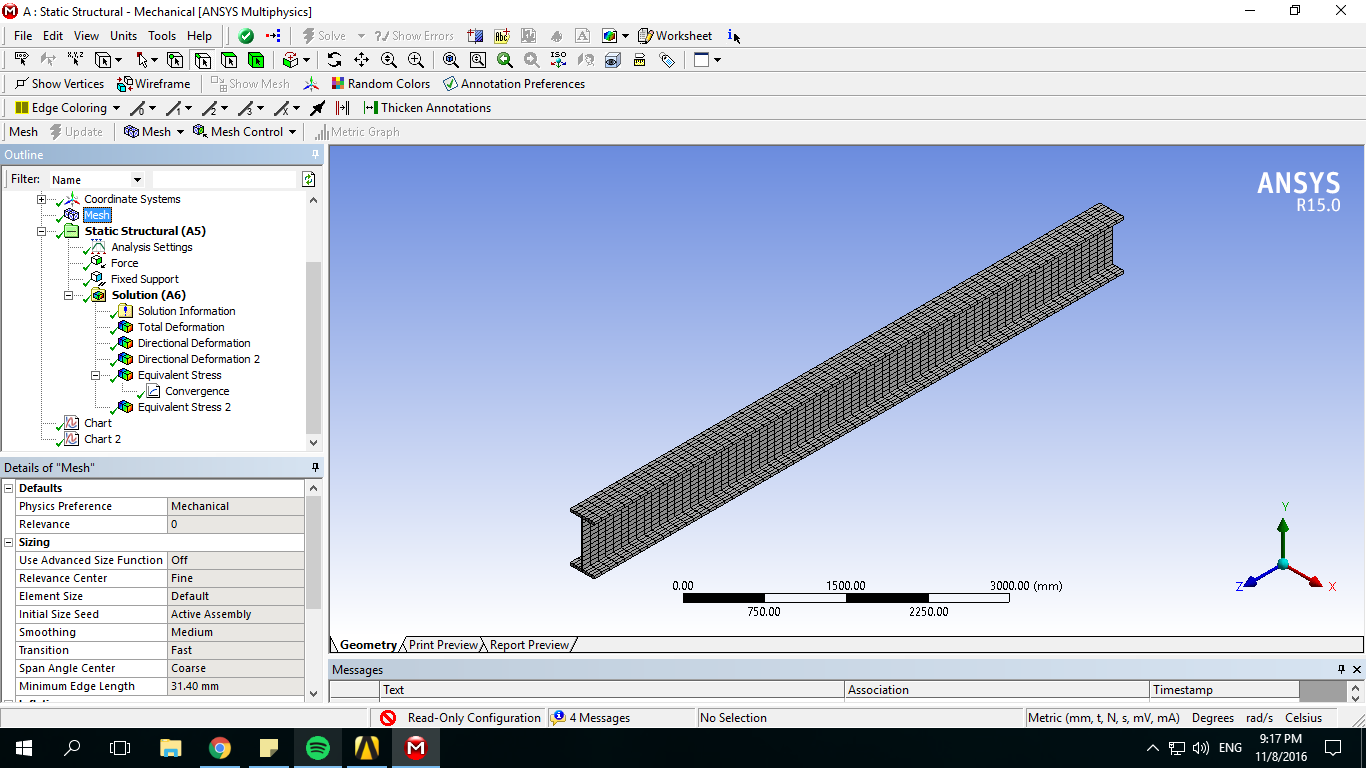


Figure 11 Meshing of 610x305x238 Beam

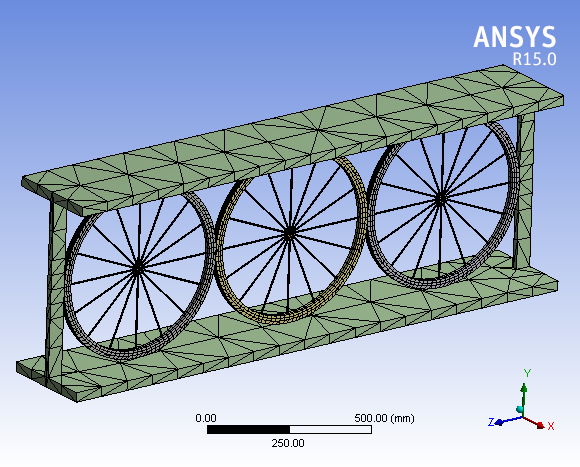


Figure 12 Meshing of New Bicycle Beam

3.3.5 Applying Load

The only applied load in the simulation model is force. Force is applied uniformly on the face of flange. A test will be carried out on distributed load of 150kN while another test will be carried out with the load in the midpoint of the flange.

3.3.6 Connection

Fully bonded connection is used in between the connection of flange to rim and rim to spokes. This is because to prevent gap in the connection and sliding is not allowed in any case. Therefore, it will restrict the movement of the material. The fully bonded connection will have no degree of freedom. In reality, this kind of contact can be archive by using welding, rivet or glue.

3.3.6 Solve

The solve command was used to initiate solving of the simulation. Solve was the last step after the model was meshed, boundary conditions defined and load has been applied. The amount of time required for solve depends on the complexity of the model and the load applied.

## **3.4 PROJECT KEY MILESTONE**

Figure 13 Key Milestone for Final Year Project I May 2016 Semester.

## **3.5 PROJECT TIMELINE**

Table 10 Gantt Chart for Final Year Project I May 2016 semester

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Activities** | **Period of Planning (week)** | | | | | | | | | | | | | |
| **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **14** |
| Selection of FYP Topic & Supervisor |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Background study on concept of prestressing of bicycle spokes. |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Conduct literature review for beam and bicycle spokes. |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Preparation of Extended Proposal for FYP 1 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Submission of Extended Proposal |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Proposal Defence & Progress Evaluation |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Continued modelling of concept. |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Preparation of Draft Interim Report. |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Preparation of Final Interim Report. |  |  |  |  |  |  |  |  |  |  |  |  |  |  |

Table 11 Gantt Chart for Final Year Project II Sept 2016 semester

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Activities** | **Period of Planning (week)** | | | | | | | | | | | | | |
| **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **14** |
| Continued modelling and analysis of model |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Data collection & tabulation |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Preparation of Progress Report. |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Submission of Progress Report. |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Data analysis and closing up of experimental works. |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Pre-SEDEX |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Preparation of draft Final Report |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Submission of Dissertation & Technical Paper (soft bound) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Viva |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Submission of Project Dissertation (hard bound) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |

# **CHAPTER 4**

# **RESULTS AND DISCUSSION**

Deflection is first tested to predict the behaviour of new beam. For comparison purpose, the bicycle rim integrated beam is fully followed the size of the selected Universal Beam.

The simulation is performed in ANSYS WORKBENCH. The simulation performed is structural simulation whereby force of 100N to 1000N is applied on each beam with the exact same size but different web. The value of force applied on each model is the same in order to compare the model sustaining the least amount of stress.

For the Universal Beam of 610x305x238 from BS4-1:20015, the maximum deflection is lower than the new bicycle rim integrated beam. It has shown how can a set of ring element can withstand the weight while decreasing the self-weight.

4.1 I-Beam Verification

An I-beam is verified using hand calculation and ANSYS simulation. The result is compared to make sure it is similar with analytic solution. There is different of 2.9% between the deflection of beam in analytic solution and ANSYS solution.

4.1.1 Manual Calculation

The deflection of beam is calculated by using Euler–Bernoulli beam equation. The maximum deflection calculated is 2.4856mm.

Maximum moment of beam is 68760kN/mm and the equivalent stress calculated is 10.529MPa.

4.1.2 ANSYS Simulation

Table 12 shows the constant of I-beam for Ansys simulation. The constant used will be same with hand calculation.

Table 12 Constant of I-beam Analysis

|  |  |  |  |
| --- | --- | --- | --- |
| Young's Modulus MPa | Poisson's Ratio | Bulk Modulus MPa | Shear Modulus MPa |
| 2.1e+005 | 0.3 | 1.75e+005 | 80769 |

Figure 14, Figure 15 and Table 13 shows the deflection result of the I-beam. The maximum deflection occur at the end of the beam where the pointed load is placed. Figure 16, Figure 17 and Table 14 shows the equivalent stress result of the I-beam.

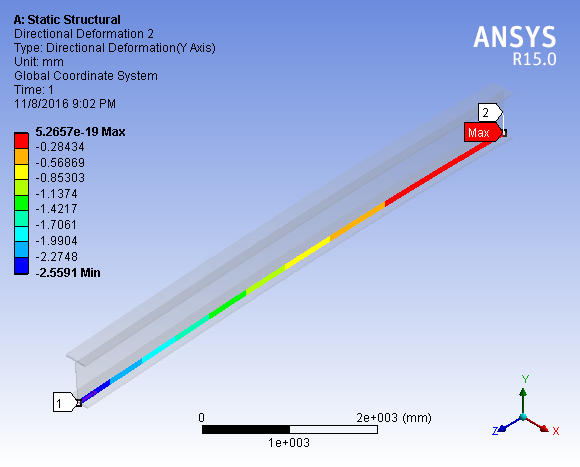


Figure 14 Deformation at Y direction of I beam

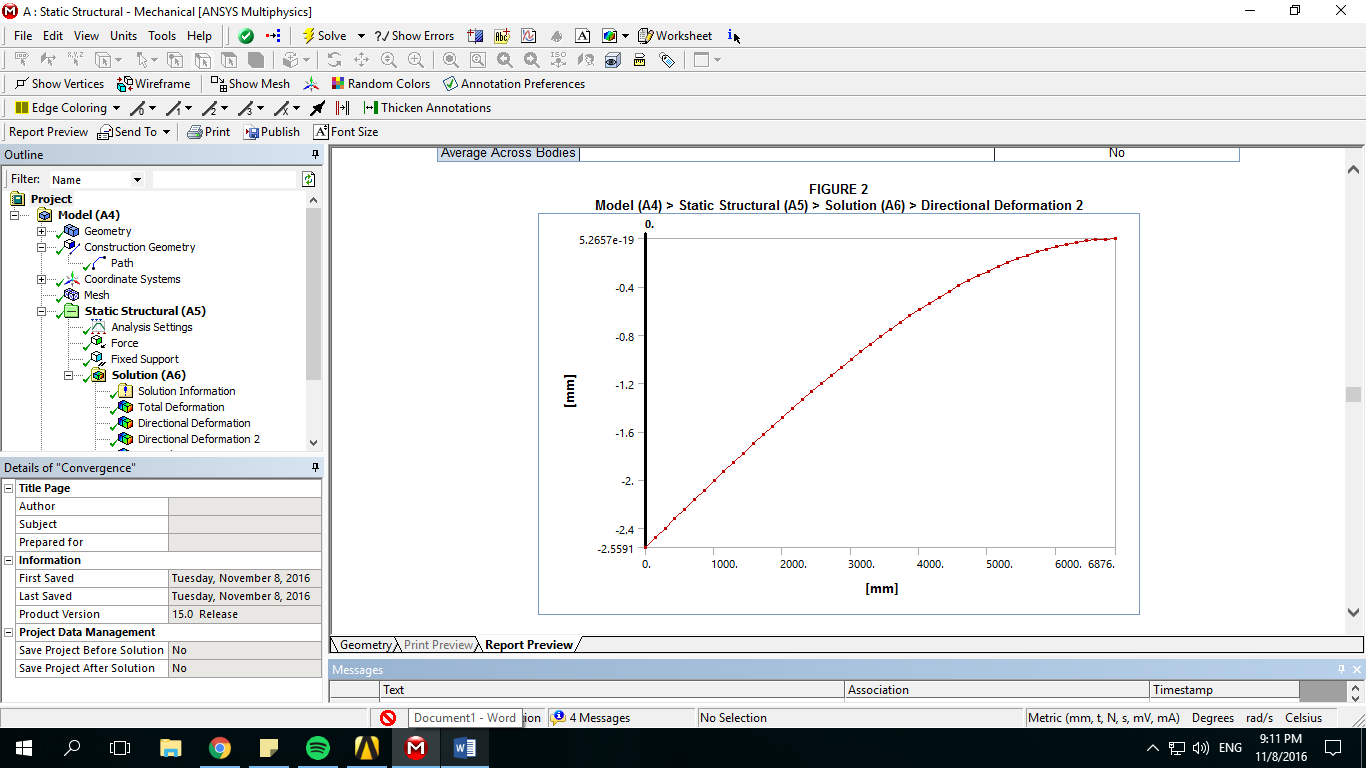


Figure 15 Length of beam vs deformation of beam

Table 13 Length of beam vs deformation of beam

|  |  |
| --- | --- |
| Length [mm] | Deformation [mm] |
| 0. | -2.5591 |
| 143.25 | -2.4785 |
| 286.5 | -2.3992 |
| 429.75 | -2.3203 |
| 573. | -2.2416 |
| 716.25 | -2.1631 |
| 859.5 | -2.085 |
| 1002.8 | -2.0073 |
| 1146. | -1.93 |
| 1289.3 | -1.8533 |
| 1432.5 | -1.7772 |
| 1575.8 | -1.7018 |
| 1719. | -1.6271 |
| 1862.3 | -1.5533 |
| 2005.5 | -1.4803 |
| 2148.8 | -1.4082 |
| 2292. | -1.3372 |
| 2435.3 | -1.2672 |
| 2578.5 | -1.1984 |
| 2721.8 | -1.1308 |
| 2865. | -1.0645 |
| 3008.3 | -0.9995 |
| 3151.5 | -0.93595 |
| 3294.8 | -0.87387 |
| 3438. | -0.81335 |
| 3581.3 | -0.75445 |
| 3724.5 | -0.69723 |
| 3867.8 | -0.64176 |
| 4011. | -0.58812 |
| 4154.3 | -0.53636 |
| 4297.5 | -0.48656 |
| 4440.8 | -0.43878 |
| 4584. | -0.39309 |
| 4727.3 | -0.34956 |
| 4870.5 | -0.30826 |
| 5013.8 | -0.26925 |
| 5157. | -0.23259 |
| 5300.3 | -0.19837 |
| 5443.5 | -0.16664 |
| 5586.7 | -0.13747 |
| 5730. | -0.11093 |
| 5873.2 | -8.7086e-002 |
| 6016.5 | -6.6009e-002 |
| 6159.7 | -4.7765e-002 |
| 6303. | -3.2423e-002 |
| 6446.2 | -2.0051e-002 |
| 6589.5 | -1.0698e-002 |
| 6732.7 | -4.2994e-003 |
| 6876. | 5.2657e-019 |

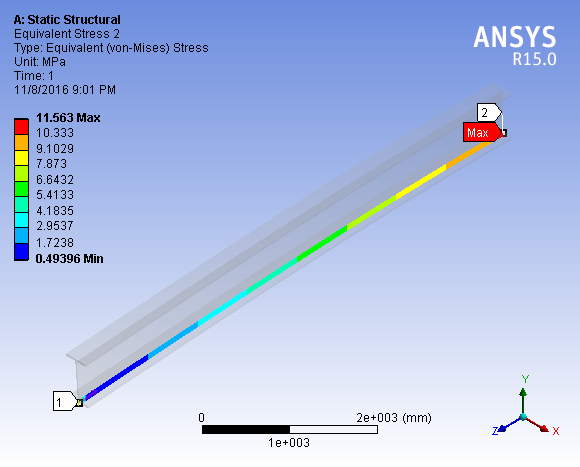


Figure 16 Equivalent (von-Mises) Stress for I beam

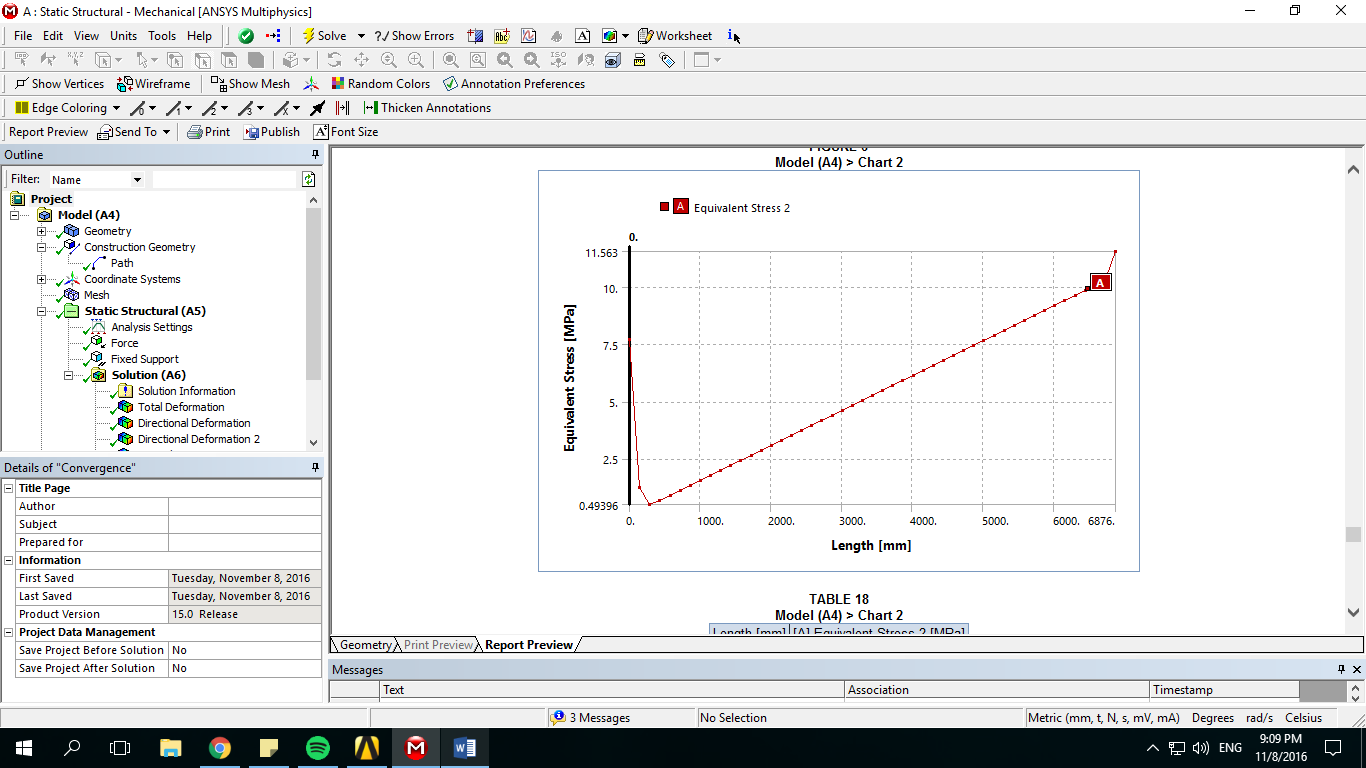


Figure 17 Length of beam vs Equivalent stress of beam

Table 14 Length of beam vs Equivalent Stress of beam

|  |  |
| --- | --- |
| Length [mm] | Equivalent Stress [MPa] |
| 0. | 7.6948 |
| 143.25 | 1.2348 |
| 286.5 | 0.49396 |
| 429.75 | 0.661 |
| 573. | 0.87476 |
| 716.25 | 1.0955 |
| 859.5 | 1.316 |
| 1002.8 | 1.5352 |
| 1146. | 1.7548 |
| 1289.3 | 1.9743 |
| 1432.5 | 2.1934 |
| 1575.8 | 2.4131 |
| 1719. | 2.6322 |
| 1862.3 | 2.8521 |
| 2005.5 | 3.0706 |
| 2148.8 | 3.2904 |
| 2292. | 3.5093 |
| 2435.3 | 3.7289 |
| 2578.5 | 3.9487 |
| 2721.8 | 4.1677 |
| 2865. | 4.387 |
| 3008.3 | 4.6065 |
| 3151.5 | 4.8259 |
| 3294.8 | 5.0448 |
| 3438. | 5.2651 |
| 3581.3 | 5.484 |
| 3724.5 | 5.7032 |
| 3867.8 | 5.9226 |
| 4011. | 6.1422 |
| 4154.3 | 6.3613 |
| 4297.5 | 6.5806 |
| 4440.8 | 6.8002 |
| 4584. | 7.0193 |
| 4727.3 | 7.2388 |
| 4870.5 | 7.4583 |
| 5013.8 | 7.6775 |
| 5157. | 7.8967 |
| 5300.3 | 8.1162 |
| 5443.5 | 8.3355 |
| 5586.7 | 8.5547 |
| 5730. | 8.7744 |
| 5873.2 | 8.9933 |
| 6016.5 | 9.2132 |
| 6159.7 | 9.4331 |
| 6303. | 9.6528 |
| 6446.2 | 9.877 |
| 6589.5 | 10.145 |
| 6732.7 | 10.351 |
| 6876. | 11.563 |

4.2 Bicycle Rim Verification

The radial load deformations of the rim were tested by the FEA model [7] without the additional displacement constraints and compare with ANSYS Simulation, with the different of 2.3%.

4.2.1 Previous Research

Simulation results for the 100 N radial load scenario without displacement constraints on the rim is 0.0522mm. [7]

* + 1. ANSYS Simulation

Figure 18 shows the model of the bicycle rim. Fixed support is located at the hub and support for X and Y direction is placed at the side of the rim. Concentrated load of 100N is applied on the top of the rim. Figure 19 shows that the rim has deformed 0.051mm on top of the rim after load is applied.

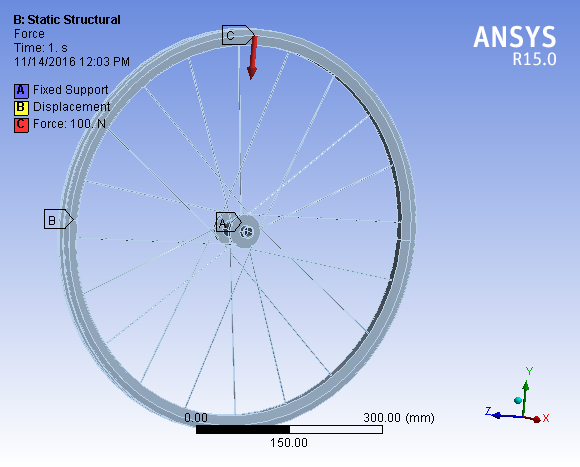


Figure 18 Boundary condition and Force placement on the rim

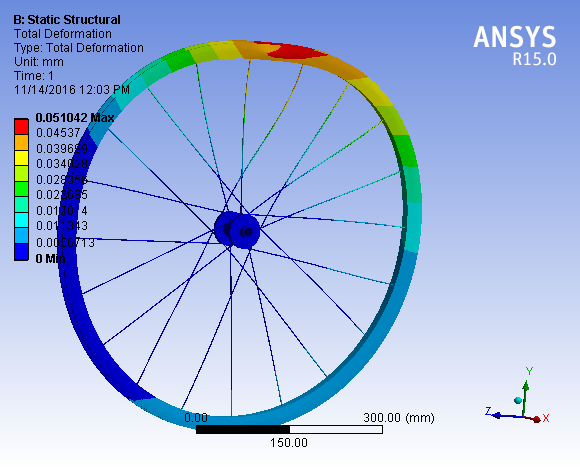


Figure 19 Result of deformation of the rim

* 1. Rim beam and I-beam Result

The result is compared between the Rim beam and I-beam. For deflection, I-beam has lower deflection than Rim beam. However, the weight of rim beam is much lower than I-beam.

4.3.1 Beam Deflection

Table 15 shows that rim beam and I-beam can take up the same load. However, the I beam has lower deflection than rim beam. This can be the cause of lack of stiffener in the beam to resist shear.

Table 15 Comparison of Deflection

|  |  |  |
| --- | --- | --- |
| Load (N) | Deflection (mm) | |
| Rim Beam | I-Beam |
| 100 | 2.56E-03 | 2.86E-05 |
| 200 | 4.06E-03 | 5.73E-05 |
| 300 | 5.55E-03 | 8.59E-05 |
| 400 | 7.05E-03 | 1.15E-04 |
| 500 | 8.54E-03 | 1.43E-04 |
| 600 | 1.00E-02 | 1.72E-04 |
| 700 | 1.15E-02 | 2.01E-04 |
| 800 | 1.30E-02 | 2.29E-04 |
| 900 | 1.45E-02 | 2.58E-04 |
| 1000 | 1.60E-02 | 2.86E-04 |

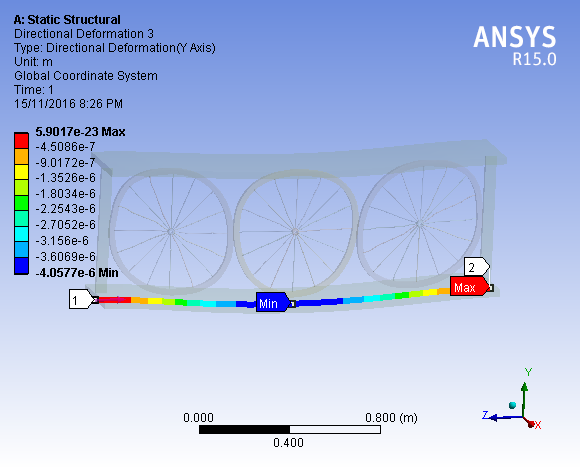


Figure 20 Deflection of New Bicycle Beam

* + 1. Weight comparison

Table 16 shows that the weight of beam is reduced when rim beam is used. It managed to reduce weight u to 27.5%.

Table 16 Comparison of weight of rim beam and I-beam

|  |  |  |
| --- | --- | --- |
|  | Rim beam | I-Beam |
| Weight | 309.19 | 426.52 |
| Difference | 27.5% | |

# **CHAPTER 5**

# **CONCLUSION AND RECOMMENDATION**

As a conclusion, the research details and objective have been clearly discussed and explained which have achieved the objective of producing this report. The simulation has been successfully performed in ANSYS. Structural load (force) has been applied on every model in order to determine the stress sustained by the models. The study show that the new beam will resist load but still far from the typical I beam. The new beam also managed to reduce about 27.5% of the typical beam weight. It can clearly reduce the cost of the material and reduce the self-weight of the beam.

Recommendations for this study would be to look into different parameters such as spoke length, spoke material, spoke diameter and the arrangement of the rim as well as the load transfer.

# **REFERENCES**

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