STRUCTURAL AND STATIC ANALYSIS ON BICYCLE FRAME USING FINITE ELEMENT METHOD

PHÂN TÍCH TĨNH HỌC KHUNG XE ĐẠP SỬ DỤNG PHẦN TỬ HỮU HẠN

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ABSTRACT

This article analyzes the stress and displacement of the bicycle frame in response to the gravitational load of the driver. As experimental frame testing is quite expensive, therefore numerical methods such as Finite Element Method (FEM) are currently applied to predict the performance of bike frame. Ansys Engineering Simulation Software are using for determining the maximum deformation and stress with static analysis. The analysis is performed based on the model built by Solidworks software. The bicycle frame used in this article is mountain bicycle form Asama called Ranger 1.0. The frame is diamond shape and made of aluminum alloy 6061. The loading cases used in this study consist of three different static loading cases with 100 kg rider weight. Static simulation results show the maximum deformation 12.075 × 10^{-5} *m. The maximum Von Mises stress from the overall loading cases is 44.1 MPa. The minimum safety factor is observed as 6.35.*

Keywords: *Bicycle Frame; FEM; Structural Analysis; Static Analysis.*

TÓM TẮT

Bài báo trình bày việc phân tích ứng suất tĩnh và chuyển vị của khung xe đạp đáp ứng theo trọng lực của người lái xe. Khi việc thí nghiệm trên khung xe rất đắt tiền thì việc dùng mô hình số và phương pháp phần tử hữu hạn để kiểm tra và dự đoán thể hiện của khung xe là rất cần thiết. Ở đây, phần mềm Ansys được dùng để xác định biến dạng và ứng suất lớn nhất trong bài toán phân tích tĩnh học. Mô hình số dùng trong phân tích phần tử hữu hạn được xây dựng bởi Solidworks và chuyển sang mô hình của Ansys. Khung xe được làm mẫu chuẩn cho việc nghiên cứu là Asama Ranger 1.0. Khung xe có dạng hình kim cương và làm bằng hợp kim nhôm 6061. Tải đặt lên khung xe gây ra bởi trọng lượng người lái 100 kg. Kết quả phân tích tĩnh học cho thấy biến dạng lớn nhất là 12,075 × 10^{-5} *m. Ứng suất Von Mises lớn nhất là 44,1 MPa. Hệ số an toàn được quan sát là 6,35.*

Từ khóa: *Khung xe; Phần tử hữu hạn; Phân tích kết cấu; Phân tích tĩnh học.*

☞

1. INTRODUCTION

Bicycles have been employed for many uses such as for transportation, bicycle commuting, utility cycling. The bicycle is also used for entertainment purposes, such as bicycle touring, mountain biking, physical fitness. There are a lot of types of bicycle competition which are held all over the world. Major multi-stage professional events are the Giro d'Italia, the Tour de France, the Vuelta a Espana, the Tour de Pologne, and the Volta a Portugal…

The bicycle has undergone continual adaptation and improvement since its inception. These innovations have continued with the advent of modern materials and computer-aided design, allowing for a proliferation of specialized bicycle types, improved bicycle safety, and riding comfort. A bicycle consists of several main parts: frame, wheel, pedal, saddle, brakes, and chain.

In this paper, theoretical approach applied the method of Finite Element Analysis (FEA) by acquiring data of force by rider applied to the bicycle frame with a purpose to identify the static structure of bicycle frame. FEA involved the usage of Solidworks Simulation to draw the frame following mountain bike measurement with aluminium alloy 6061 material. Use Ansys, which is a software that enables the adoption of finite element analysis, to analyse the structural properties like stress and displacement. From the results obtained, we will try to find solutions to overcome shortcomings when designing bicycle frames as well as frame manufacturing materials.

2. REVIEW OF BICYCLE FRAME

The basic requirements for a bicycle frame are top tube, head tube, down tube, chain stays, seat stay, and seat tube. The double triangle shape of bicycle frame is known as a diamond frame. Various loads are acting on the different parts of a bicycle frame. In this study, the rider with 100 kg was considered to analyze the static and dynamic analysis of the alunimium alloy Al6061 T6 frame by FEM.

The material properties are shown in Table 1. The primary dimension of the bicycle frame are shown in Table 2. Figure 1 show the diagram of tube.

Table 1. Material properties

Aluminium Alloy 6061		
Data	Symbol	Value
Young’s Modulus	E	70 GPa
Density	p	2700kg/m^3
Poission’s ratio	v	0.34

Table 2. Dimensions of main part

Part	**Length (mm)**	**Outer Diameter (mm)**	**Inner Diameter (mm)**
Top tube	50	40	38
Head tube	10	40	38
Down tube	60	40	38
Seat tube	40	40	38
Seat stays	45	20	0
Chain stays	42.5	20	0

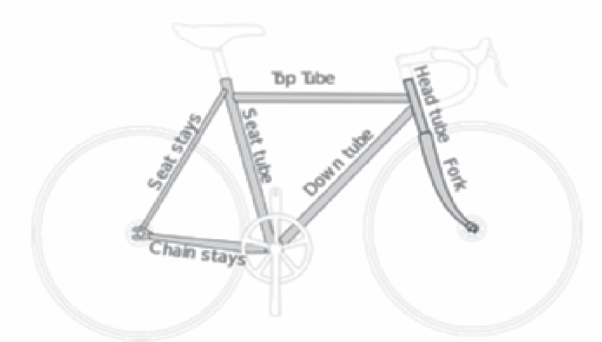


Figure 1. Diagram of tube

3. FEA OF BICYCLE FRAME USING ANSYS

To verify the analytical result of deformation for bicycle frame it is compared with FEA analysis and define the stress. The problem to be modeled is a simple bicycle frame shown in the following Figure 2. The model then is meshed as in Figure 3.

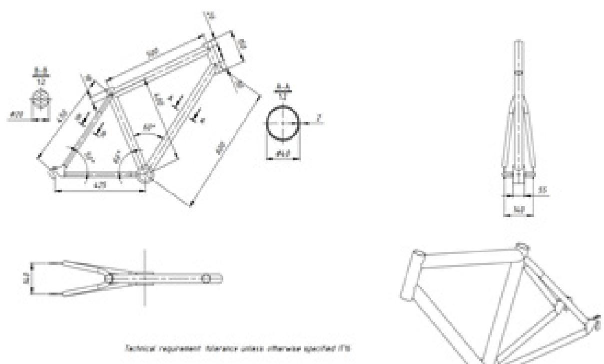


Figure 2. Model Solidworks

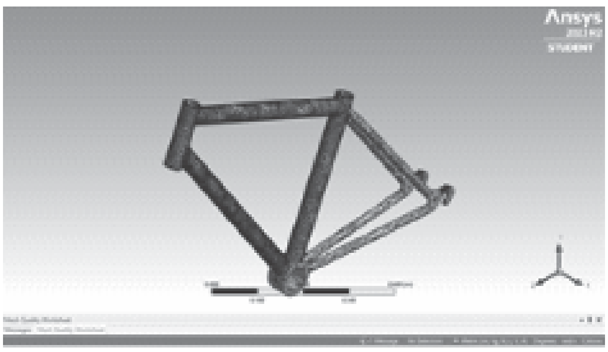


Figure 3. Meshed bike frame model

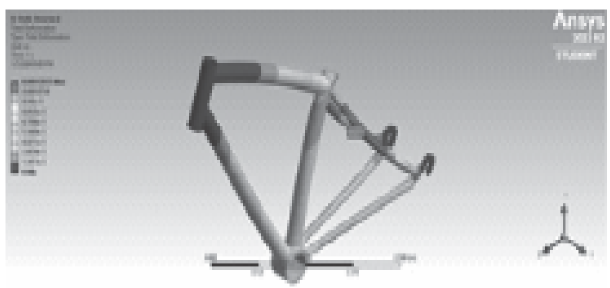
The static structural analysis is made by applying loads and constraints to the frame at several points and the positions and analysis is done for the frame as Figure 4.

In the figure point D is the fixed support where the front part of the frame goes and rests on the fork of the steering. Point E is the fixed support where the frame rests on the dropout of the rear wheel of the bicycle near the dropouts. Point A is load acting on the frame that is at the area of the saddle location, the load considered is 1000N on the frame which is 100kg of rider. Point B is 150N load acting on the handle of bicycle. Point C is 450N load acting on the pedal of the bike.

Figure 4. Constrains and loads acting on the frame

After all the forces are applied on the frame and the structural constrains given after the meshing the deformation results, stresses on the frame are obtained and the conclusions are made based on the amount of maximum deformation and stress (Figure 5,6,7).

- Deformation



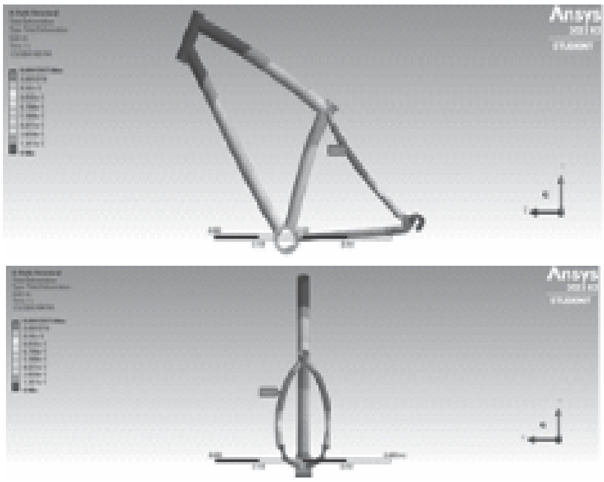


Figure 5. Deformation of bicycle frame

The result after analysis on Ansys shows that the maximum deformation of bike frame is on the seat stays and it's value is 12.075×10^{-5} m.

⇨ Comment: The result of bicycle's deformation let us know the rigidity of bicycle (the greater the rigidity, the smaller deformation and vice versa). Based on that, in the future we can find ways to increase the rigidity of the bicycle frame.

- Von Mises Stress

One of the outputs of finite element analysis is Von Mises stress which can be used to estimate the possibility of plastic deformation in the structure. The output of the static linear simulation is Von Mises stress distribution. It can be seen that the Von Mises stress plot on the frame model is depicted using color contours. The lowest stress contour is depicted in blue, while the highest stress contour is depicted in red. The color contours displayed on the frame model can be used to determine the stress distribution in the frame.

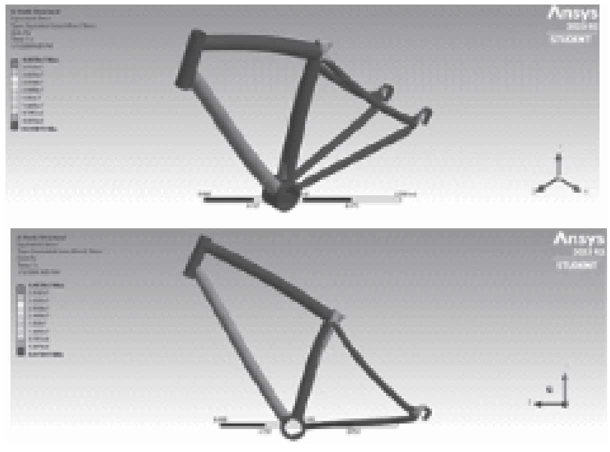


Figure 6. Von Mises stress distribution

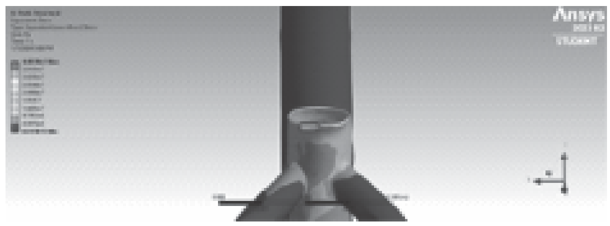


Figure 7. Von Mises stress distribution on sitting position

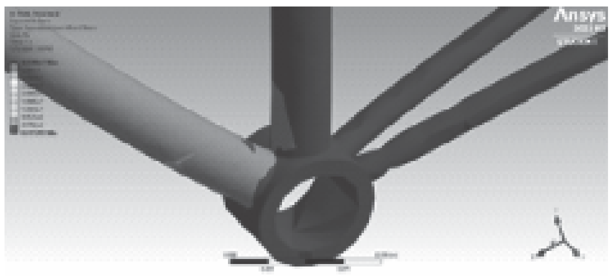


Figure 8. Von Mises stress distribution between the seat and down tube

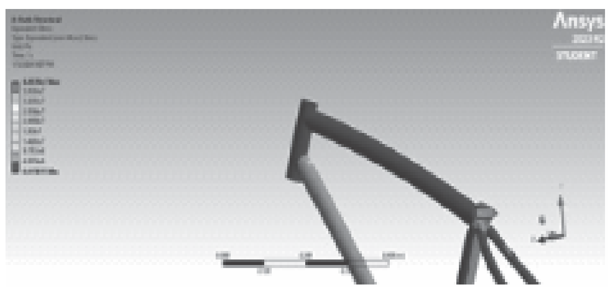


Figure 9. Von Mises stress distribution between the head and top tube

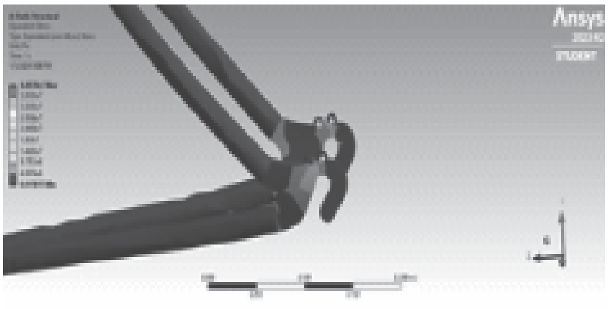


Figure 10. Von Mises stress distribution on the connection between the wheel and chain stays

⇨ Comment: The simulation for the bike frame model with static loading in the sitting riding position shows that the maximum stress that occurs is 44.1 Mpa. The maximum stress concentration occurs around the area between the seat tube and the top tube connection as shown in Figure 8. Locations where notable Von Mises stress values appear are shown in the Figure 9, Figure 10, Figure 11 and Figure 12.

- Safety factor

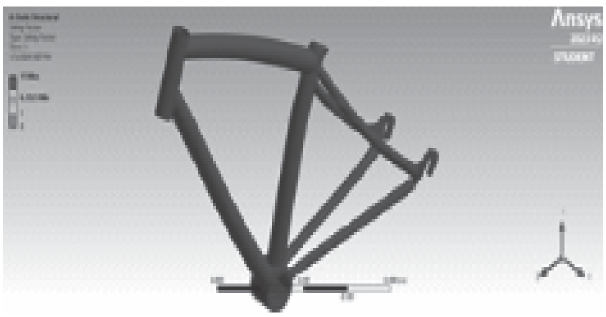


Figure 11. Safety factor of bicycle frame

⇨ Comment: The result shows that the frame can endure all the loads acting on it. The value at the top of the seat tube is the lowest since the equivalent stress at this area is the highest. Oppositely, the area which has the low to medium equivalent stress has the highest safety factor value. In conclusion, the frame is safe for normal operation.

Figure 12. Minimum safety factor

4. CONCLUSION

The analysis of this bicycle frame was based on the specific boundary condition of adult's weight of 100 kg. The bicycle frame is made from aluminum alloy Al6061 T6. Ansys let us know exactly positions stand with minimum, maximum Von Mises stress and the area has minimum safety factor. Although the deformation occurs, the bicycle frame can still endure the stress without any damage on the frame structure. In conclusion, the results are acceptable and can be improved in the future. Hence, the objective for the project is achieved.❖

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