MODAL ANALYSIS OF BICYCLE FRAME USING FINITE ELEMENT METHOD

PHÂN TÍCH DẠNG DAO ĐỘNG KHUNG XE ĐẠP SỬ DỤNG PHẦN TỬ HỮU HẠN

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ABSTRACT

This paper deals with the validation of vibration analysis of a simple bike chassis. Vibrations are the phenomenon observed by bodies where oscillations take place about an equilibrium point. It is observed in every component. Vibrations in some cases are an unnecessary phenomenon. Vibrations induce cyclic loads which lead to fatigue failure which in turn reduced the lifetime and durability of the product. Modal analysis is one of the methods applied to find the vibration characteristics of a structure. With the help of Ansys software, we can infer how the chassis behaves at different frequencies. The bicycle frame used in this article is diamond shape and made of aluminum alloy 6061.

Keywords: *Bicycle Frame; FEM; Modal Analysis; Natural Frequency; Mode Shape.*

TÓM TẮT

Bài báo trình bày việc phân tích dạng dao động của khung xe đạp đơn giản. Dao động là hiện tượng mà vật thể chuyển động qua lại vị trí cân bằng. Dao động trong nhiều trường hợp là không cần thiết vì nó liên quan tới tải thay đổi co chu kỳ dẫn tới hư hỏng do mỏi, giảm tuổi thọ của sản phẩm. Phân tích dạng dao động là một trong những phương pháp được áp dụng để tìm ra các đặc tính rung động của kết cấu. Với sự trợ giúp của phần mềm Ansys, chúng tôi có thể xác định được cách hoạt động của khung xe ở các tần số riêng khác nhau. Khung xe đạp được sử dụng trong nghiên cứu này có dạng hình kim cương và được làm bằng hợp kim nhôm 6061.

Từ khóa: *Khung xe; Phần tử hữu hạn; Tần số riêng; Dạng dao động.*

☞

1. INTRODUCTION

Vibrations are one of the underlying phenomena experienced in every day to day object. Cyclic loads produce stress withing the structures which reduce the strength and life of the object in use. If the frequency of the driving force matches one of the natural frequencies of the object, it causes deflections of huge amplitudes. Understanding the nature and attempting to study its properties helps us in understanding the dynamic properties of a structure and measuring its vibration parameters. Based on the object under study, we need to select an appropriate method of testing. Taking the bicycle frame into account, the problem we are faced with is to study its modal properties and compare the static modal study with the operational effects induced by the running engine on the chassis. In this paper, we attempt to find out the natural frequencies of the frame, the mode shapes generated with computer simulations, and validate this with experimental data acquired via modal analysis.

Modal analysis is an essential technique in structural engineering and design, used to study the dynamic behavior of structures under different loading conditions. It helps engineers understand the natural frequencies, mode shapes, and damping characteristics of a structure, providing valuable insights into its response to vibrations and oscillations. We use Ansys, a widely-used engineering simulation software, offers powerful tools for conducting modal analysis.

2. MATERIAL

This paper is modal analysis of bicycle frame so the material for making the bicycle also has an impact on the results because material decide the strength of frame. High compressive and tensile strength of frames assured safety of users and also it increases the life of bicycle frame. At present the materials are used for making bicycle frame as various mechanical properties. Steel, Aluminum Alloy, Titanium, Carbon Fiber etc. used as common material in frame construction.

Among all generally aluminum alloy (6061 Al of series 6000) with composition of Si and Mg are most usable as it has high weldability, light weight, high strength (at stresses) and good corrosion properties. That's why we chose aluminum alloy 6061 as the material for the bicycle frames analyzed in this paper. The mechanical properties of Al6061 are shown in the table below.

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

3. MODELLING OF BICYCLE FRAME

The bicycle frame is designed in Solidworks, after making model in Solidworks, model file named XYZ.IGS is imported in Ansys software. Static structural is selected for the analysis. The mass of this model is 2.2 kg.

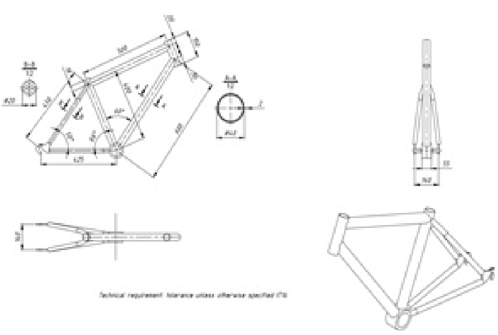

Figure 1. Model Solidworks of bicycle frame

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4. FEM ANALYSIS OF BICYCLE FRAME USING ANSYS

- Meshing and details

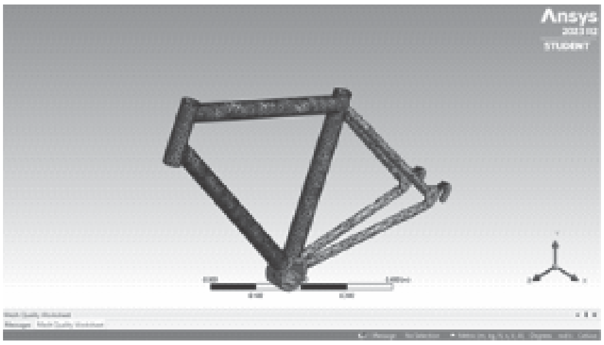

Figure 2. Meshed bike frame model

Display	
Display Style	Use Geometry Setting
Defaults	
Physics Preference	Mechanical
Element Order	Program Controlled
Element Size	Default
Sizing	
Use Adaptive Sizing	Yes
Resolution	Default (2)
Mesh Defeaturing	Yes
Defeature Size	Default
Transition	Fast
Span Angle Center	Coarse
Initial Size Seed	Assembly
Bounding Box Diagonal	1.0719 m
Average Surface Area	5.8964e-003 m²
Minimum Edge Length	9.8042e-005 m
Quality	
Inflation	
Advanced	
Statistics	
Nodes	58009
Elements	28580
Show Detailed Statistics	No

Figure 3. Details of mesh

- Modal analysis

The meshed model was imported on Ansys to perform modal analysis. The first 6 modes were analyzed along with the frequencies.

Tabular Data

	Mode	Frequency [Hz]
1	1.	104.91
2	2.	171.24
3	3.	290.94
4	4.	320.49
5	5.	330.27
6	6.	399.11

Figure 4. 6 first natural frequencies of bicycle frame

+ Mode 1 = 104.91 Hz

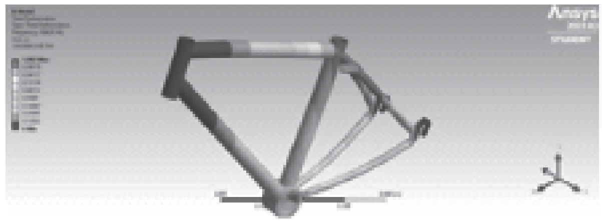

Figure 5. Mode 1

⇨ Comment: For mode 1, the natural frequency value is 104.91 Hz, where the maximum deformation occurs on the area of the seating and area between 2 seat stays and seat tube, while the minimum deformation occurs on the joints of chain stays and seat stays and head tube.

+ Mode 2 = 171.24 Hz

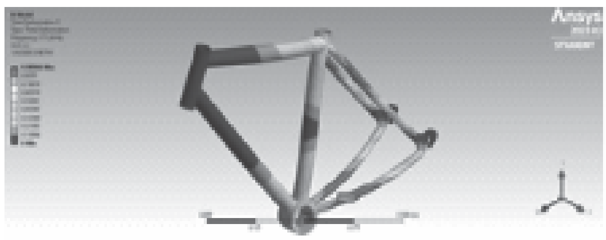

Figure 6. Mode 2

⇨ Comment: For mode 2, the natural frequency value is 171.24 Hz, where the maximum deformation occurs on the middle of 2 seat stays and 2 chain stays. In contrast, the minimum deformation occurs on the joints of chain stays and seat stays and head tube. ☞

+ Mode 3 = 290.94 Hz

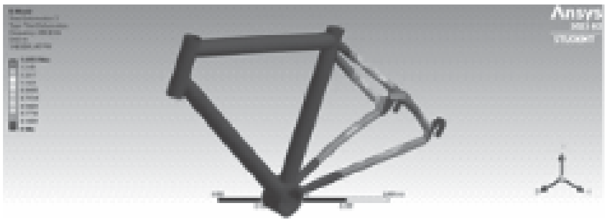

Figure 7. Mode 3

⇨ Comment: For mode 3, the natural frequency value is 290.94 Hz, where the maximum deformation occurs on the middle of 2 seat stays. In contrast, the minimum deformation occurs on other parts except chain stays.

+ Mode 4 = 320.49 Hz

⇨ Comment: For mode 4, the natural frequency value is 320.49 Hz, where the maximum deformation occurs on the area of the middle of 2 seat stays. In contrast, the minimum deformation occurs on the joints of chain stays and seat stays and head tube.

Figure 8. Mode 4

+ Mode 5 = 330.27 Hz

Figure 9. Mode 5

⇨ Comment: For mode 5, the natural frequency value is 320.27 Hz, where the maximum deformation occurs on the area of the middle of 2 seat stays. In contrast, the minimum deformation occurs on the joints of chain stays and seat stays and head tube.

+ Mode 6 = 399.11 Hz

Figure 10. Mode 6

⇨ Comment: For mode 6, the natural frequency value is 399.11 Hz, where the maximum deformation occurs on the area of the middle of 2 chain stays. In contrast, the minimum deformation occurs on the joints of chain stays and seat stays and head tube.

The table summary of modal analysis

Mode	Natural frequency	Maximum deformation	Minimum deformation
Mode 1	104.91 Hz	- The seating - The area between 2 seat stays and seat tube	- The joints of chain stays and seat stays - Head tube
Mode 2	171.24 Hz	- The middle of 2 chain stays - The middle of 2 seat stays	- The joints of chain stays and seat stays - Head tube

Mode 3	290.94 Hz	- The middle of 2 seat stays	- Other parts except chain stays
Mode 4	320.49 Hz	- The middle of 2 seat stays	- The joints of chain stays and seat stays - Head tube
Mode 5	330.27 Hz	- The middle of 2 seat stays	- The joints of chain stays and seat stays - Head tube
Mode 6	399.11 Hz	- The middle of 2 chain stays	- The joints of chain stays and seat stays - Head tube

5. CONCLUSION

The analysis of this bicycle frame was based on the specific condition. The bicycle frame is made from aluminum alloy Al6061 T6. The vibration analysis is conducted using FEA to obtain the six modes of frequency. From this analysis, future study can proceed on the frame to avoid these natural frequencies or minimize the vibration and deformation when the frame reaches near these frequencies. The results also show the small deformation that occurs on the bicycle frame during normal operation. 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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