A Study on Multiple Load Conditions Analysis for a Conventional Bicycle vs. a Variable-Chain Stay-Length (VCL) Bicycle De1

Meor Rashydan Abdullah[1], Muhammad Izzat Nor Ma'arof[2*], Winson Wong Zu Xian[2], Suresh Akshith[2], Girma Tadesse Chala[3]

[1]Faculty of Faculty of Business, Communication and Law, INTI International University, Persiaran Perdana BBN, Putra Nilai, 71800 Nilai, Negeri Sembilan, Malaysia
[2]Faculty of Engineering and Quantity Surveying (FEQS), INTI International University, Persiaran Perdana BBN, Putra Nilai, 71800 Nilai, Negeri Sembilan, Malaysia
[3]International College of Engineering and Management, P.O. Box 2511, C.P.O Seeb 111, Muscat, Oman

*__Email:__ muhammadIzzat.maarof@newinti.edu.my

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Abstract: The aim of this study was to study on the multiple loading conditions on a varied bicycle's chain stay designs. The benchmark for this study was a conventional bicycle chassis design which is available in the market. The specification details of this chassis were obtained from the manufacturer's website. The new design was a Variable-Chain Stay-Length (VCL) configuration. The purpose for the VCL is to allow room for the cyclist to attach to have an extra space for placing the cargo. The VCL is rated as VCL De1 and was developed in reference to the aforementioned benchmark chassis. Both chassis were developed via the use of Computer Aided Design (CAD). The chassis were then analyzed via Finite Element Analysis (FEA) software for the following loading conditions: (i) Static start-up (ii) Steady pedaling (iii) Vertical loading (iv) Rear wheel braking. The Maximum Equivalent (von Mises) Stress (MPa) recorded for the loading conditions were as follow: (i) Benchmark Chassis: (Condition 1) 117.58MPa, (Condition 2) 120.51MPa, (Condition 3) 235.15MPa, (Condition 4) 99.40MPa, whilst, for the (ii) VCL De1: (Condition 1) 123.43MPa, (Condition 2) 126.24MPa, (Condition 3) 246.85MPa, (Condition 4) 189.13MPa respectively. Adding to this, the safety factor for the aforementioned conditions were also obtained as follow: (i) Benchmark Chassis: (Condition 1) 2.38, (Condition 2) 2.32, (Condition 3) 1.19, (Condition 4) 2.82, whilst, (ii) VCL De1: (Condition 1) 2.03, (Condition 2) 1.98, (Condition 3) 1.01, (Condition 4) 0.13. In short, the assessments were a success. It could be noted that the safety factors for the VCL De1 is above 1.0 for Condition 1 to 3, yet, at condition 4 is rated at 87% below the Safety Factor. Hence, this result is indeed undesirable. Thus, the VCL De1 is not suitable for usage due to the high possibility of structural failure. Further improvement on design iteration is warranted for the VCL chassis

Keywords: Bicycle, Chassis, Finite Element Analysis, Loading Conditions

Introduction

In Malaysia, mass utilization of bicycle as a “green approach” in ensuring environmental sustainability and minimizing over reliant on fossil fuel is indeed a great idea. One of the prominent component of a bicycle is its chassis. Chassis is the main part of a bicycle, where it absorbs all the load acting on it as noted by Nor et al., (2019). The chassis plays important role in of safety as well as comfort.

The aim of this study was to study on the multiple loading conditions on a varied bicycle’s chain stay designs. The benchmark for this study was a conventional bicycle chassis design which is available in the market. The specification details of this chassis were obtained from the manufacturer’s website. The new design was a Variable-Chain Stay-Length (VCL) configuration. The purpose for the VCL is to allow room for the cyclist to attach to have an extra space for placing the cargo. The VCL is rated as VCL De1 and was developed in reference to the aforementioned benchmark chassis.

Upon the successful development of the Variable-Chain Stay-Length (VCL) Bicycle, such bicycle could be a good option for commuting among the city dwellers. The extra space for placing a cargo on the bicycle provides the convenience of goods transportation or luggage placement by the cyclist. Overtime, this shall facilitate for the establishment of potential green-cities/town in the various urban areas in Malaysia.

Methodology

Both chassis were developed via the use of Computer Aided Design (CAD). The chassis were then analyzed via Finite Element Analysis (FEA) software for the following loading conditions: (i) Static start-up, (ii) Steady pedaling, (iii) Vertical loading, and (iv) Rear wheel braking. The five scenarios of each load conditions are show below:

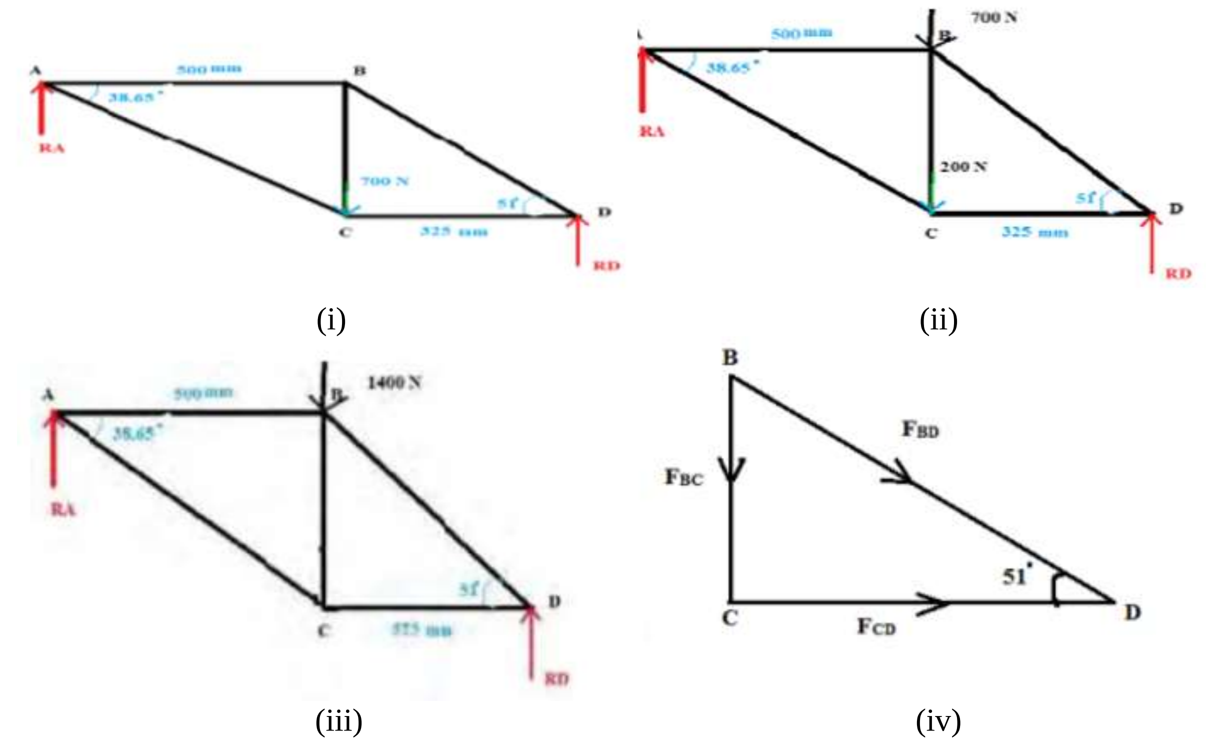

Figure 1. (i) Static start-up, (ii) Steady pedalling (iii) Vertical loading, and (iv) Rear wheel braking

Static start-up

In this scenario is modelling the rider is riding the bicycle in the stationary position. The front wheel of the bicycle is pointed straight in the vertical equilibrium. There are some variables is negligible such as aerodynamics, rolling and gyroscopic force as noted by Pawar, R. and Kolhe, K., 2016. The weight of the rider is 71.3kg which applied a load of 700N to the seat tube of the bicycle frame in accordance to Devaiah et al., (2018).

Steady pedalling

This scenario is modelling the rider with the weight of 700N starts to apply a steady pedalling to the bicycle and maintains the power of pedalling at all times. The pedalling force is 200N due to leg dynamics in referring to Devaiah B. et al, (2018). The load is concentrate at the bottom bracket of the bicycle frame.

Vertical loading

In this scenario, the vertical loading will be double of the weight of the rider because of the present of the G factor. The double weight situation is representing the scenario of the bicycle cycling through a deep road hole which will make an impact. The impaction will transfer the energy to the whole structure body. Therefore, the load represent the weight of the rider is 1400N in this load condition.

Rear wheel braking

The scenario is related to the brake on the rear wheel. Assumption is made that the obstruction has been given slowly to the wheels and the loads are focused on the rear wheel. The rider needs to decrease the speed to achieve steady speed. Then, the rider needs to brake the bicycle until it stops. In this condition, the load of 200N is given to the rear drop outs because of the consideration of brakes in accordance to Akhyar et al., (2019).

Result and Discussion

Table 2. The reading and position of maximum equivalent (Von Mises) stress in expandable mode under load condition 1

Design Expandable Mode	Stress (MPa)		Safety Factor	Position
	Maximum	Minimum		
Benchmark	117.58	0	2.38	Top of Seat Tube
Design 1	123.43	0	2.03	

Table 3. The reading and position of maximum equivalent (von Mises) stress in expandable mode under load condition 2

Design Expandable Mode	Stress (MPa)		Safety Factor	Position
	Maximum	Minimum		
Benchmark	120.51	0	2.32	Joint between Seat Tube and Bottom Bracket

Design 1	126.24	0	1.98	Chain Stays

Table 4. The reading and position of maximum equivalent (von Mises) stress in expandable mode under load condition 3

Design Expandable Mode	Stress (MPa)		Safety Factor	Position
	Maximum	Minimum		
Benchmark	235.15	0	1.19	Top of Seat Tube
Design 1	246.85	0	1.01	

Table 5. The reading and position of maximum equivalent (von Mises) stress in expandable mode under load condition 4

Design Expandable Mode	Stress (MPa)		Safety Factor	Position
	Maximum	Minimum		
Benchmark	99.40	0	2.82	Chain Stays
Design 1	189.13	0	0.13	

The Maximum Equivalent (von Mises) Stress (MPa) recorded for the loading conditions were as follow: (i) Benchmark Chassis: (Condition 1) 117.58MPa, (Condition 2) 120.51MPa, (Condition 3) 235.15MPa, (Condition 4) 99.40MPa, whilst, for the (ii) VCL De1: (Condition 1) 123.43MPa, (Condition 2) 126.24MPa, (Condition 3) 246.85MPa, (Condition 4) 189.13MPa respectively (See Tables 3 and 4). Adding to this, the safety factor for the aforementioned conditions were also obtained as follow: (i) Benchmark Chassis: (Condition 1) 2.38, (Condition 2) 2.32, (Condition 3) 1.19, (Condition 4) 2.82, whilst, (ii) VCL De1: (Condition 1) 2.03, (Condition 2) 1.98, (Condition 3) 1.01, (Condition 4) 0.13.

The mechanical properties of 6061 aluminum alloy measure the alloy’s stiffness, or resistance to deformation. Its Young’s modulus is 68.9 GPa and its elongation is 17 % which is the highest among the other materials shown in Table 1. Generally, this alloy is easy to be joined via welding and readily deforms into the most desired shapes, making it a versatile manufacturing material. Additionally, the two important factors when considering mechanical properties are yield strength and tensile strength. The yield strength describes the maximum amount of stress needed to elastically deform the part in a given loading arrangement. The tensile strength, on the other hand, describes the maximum amount of stress a material can withstand before fracturing. For static applications, the yield strength is the more important design constraint where Al 6061 has a value of 276MPa, and a tensile strength of 310MPa that can be useful for certain applications such as dynamic loading. Lastly, 6061 aluminum alloy is readily available and cheaper thus for all these reasons this material is chosen for this study.

Conclusions

In short, the assessments were a success. It could be noted that the safety factors for the VCL De1 is above 1.0 for Condition 1 to 3, yet, at condition 4 is rated at 87% below the Safety Factor. Hence, this result is indeed undesirable. Thus, the VCL De1 is not suitable for usage due to the high possibility of structural failure. Further improvement on design iteration is warranted for the VCL chassis for the purpose of continuous improvement and sustainability.

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