A Study on Building a Motorcycle Finite Element Model for Crashworthiness Base on the Current Transportation in Vietnam

Nguyen Phu Thuong Luu and Ly Hung Anh

Abstract This study aimed to construct a finite element model of a small motorcycle with full deformability for simulating frontal crashes, and to provide a comprehensive guide for the entire development process. The Honda Wave 110 cc, a Vietnamese national motorcycle, was selected as the physical motorcycle, and the model was analyzed in the LS-DYNA environment. This paper presents a tutorial on advanced 3D modeling to generate a high-quality 3D geometry and replication model of a motorcycle chassis, and then to set up a model dummy sitting on the motorcycle. This motorcycle FE model can be utilized for crashworthiness analysis and other studies. The motorcycle model was constructed from different materials such as steel and aluminum to make the motorcycle chassis model. The frame of the motorcycle was created by combining the individual parts of the saddle, handlebar, and wheel. The entire model of the motorcycle was then meshed and assigned materials, and its stability was assessed by conducting a crash simulation with a vehicle model. The dummy part was also added to the motorcycle model so that it could be employed to assess the injury of motorcyclists when a collision with other types of traffic occurs.

Keywords FEM · Model · Design · Structure · Vietnamese motorcycle

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1 Introduction

Today, the problem of traffic accidents is being warned of worldwide. Especially in developing countries, there are a lot of motorbikes, including in Vietnam. However, there has not been any research on popular motorcycles in Vietnam when they collide. Most studies focus on cars, buses, and trucks [1–5]. For that reason, this paper builds a popular motorcycle model widely used on the market today for research. After building this motorcycle model, it can be used to study the structure and safety when colliding with other vehicles. This paper discussed the use of a dummy to evaluate post-collision head injury and the combination of motorcycle and dummy models to simulate real-world collisions. There are a few studies related to motorcycle structure, as in the article [6]. As mentioned in this article, research on improving crash safety for large motorcycles of this type is not very common in Vietnam. Similarly, there is a study number [7] which focused on the frame structure of a 4-wheel off-road motorcycle only used for off-road areas. This study examined the safety of motorcyclists in collisions with cars, using a popular motorcycle model in Vietnam [8]. The focus was on analyzing the dummy's head injury, with the motorcycle structure assumed to be undistorted.

1.1 Motorcycle Model Design

This study used CATIA V6 design software to create a 3D motorcycle frame based on the Honda Wave 110cc (Fig. 1), a popular model in Vietnam. The parts of the frame were refined for increased realism and accuracy, and the model was mapped for size, mass, and precision to simulate a dummy ride.

This study focused on the main frame structure, with the bearing parts being the most impacted in the event of an impact. The plastic truss parts outside the body were omitted to simplify the motorcycle model. The details of the model were designed below.

Fig. 1 Honda Wave 110cc was selected to design the motorcycle model

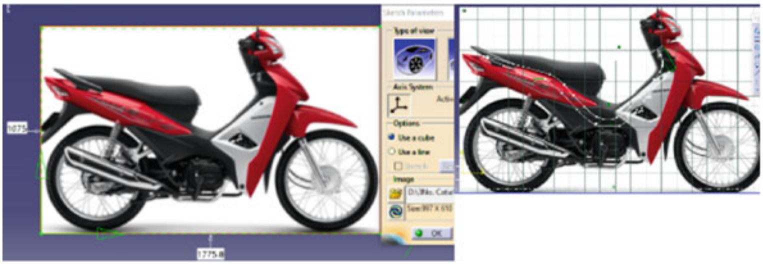


Fig. 2 Size reference from real motorcycle model

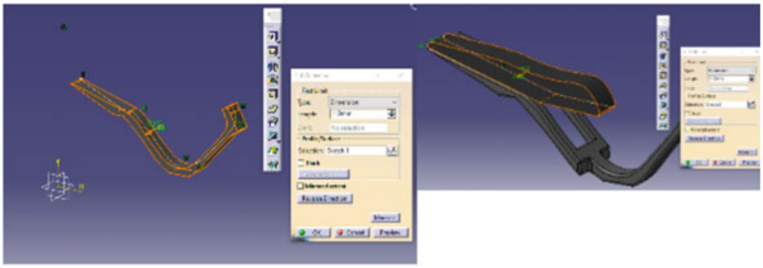


Fig. 3 Motorcycle frame model design process

1.2 Motorcycle Chassis

The motorcycle model's frame was redesigned based on the physical size of the Honda Wave motorcycle (Fig. 2) to determine the size of the motorcycle model. The frame part was designed accordingly (Fig. 3).

1.3 Motorcycle Wheel and Suspension

The wheel part is designed with wheels and rims. The size is taken according to the actual size in which to simplify the design of the wheel as shown in Fig. 4.

This study focused on the structural part of the motorbike, omitting the kinematic part. To simplify the model, the front and rear suspension systems were simplified with hard-link bars (Fig. 5).

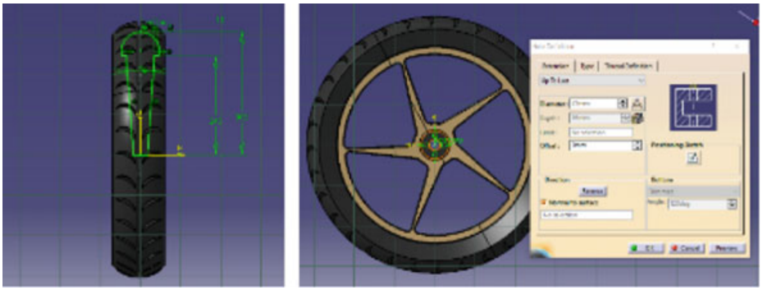


Fig. 4 Wheel design process for motorcycle model

Fig. 5 Motorcycle suspension system design

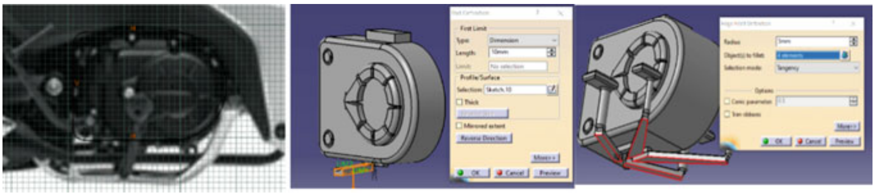


Fig. 6 Motorcycle engine model design

1.4 Motorcycle Engine

The engine model was designed with a focus on the exterior shape and size, while internals were simplified to simplify the model. The engine mass was added to match the real engine's mass. The design process is shown in Fig. 6.

1.5 Full Motorcycle 3D Model

The motorcycle handlebar model is simplified, leaving only the control bar, and other parts such as handbrake, cables, taplo meter and control buttons are omitted.

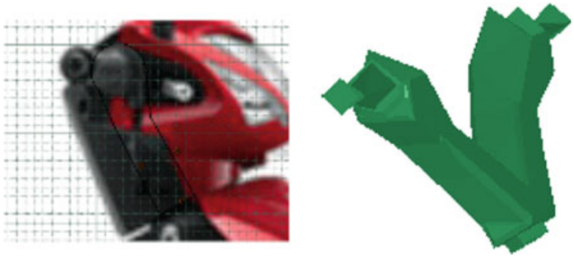


Fig. 7 Motorcycle handlebar model design

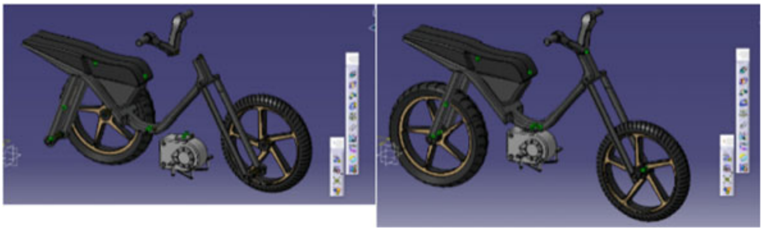


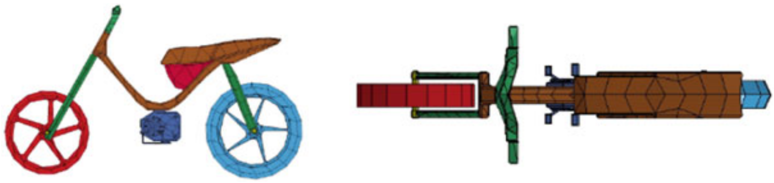
Fig. 8 Full assembled motorcycle model

The steering wheel model is designed as shown in Fig. 7. In Fig. 8 on the left are all the details of the motorcycle model after being designed in 3D. After assembling the parts together, we have a complete motorcycle model as shown in Fig. 8 on the right.

1.6 Simulations Set up

1.6.1 Create Mesh Mode and Materials

To simulate, we have to perform the meshing of the motorcycle model designed above and set up boundary conditions as well as collision conditions in reality. In this paper, meshing is done using Hypermesh software. Because the model is the same size as the real car, the details are large. Therefore, the element size of the selected details is 10 mm when meshing. If high precision is not required, we can choose an element size of 50 mm. Depending on the size of the details, we can resize the element accordingly. The model after meshing is shown in Fig. 9. The materials used in the motorcycle model are based on the material description in the LS-DYNA software. Because the details in the motorcycle model are deformable, MAT 24 is mainly used for metal materials, and MAT 07 is used for rubber materials such as tires.



a. Side view b. Top view

Fig. 9 The motorcycle model has been meshed and added materials

Fig. 10 Motorcycle model with dummy

1.7 Set up the Dummy's Posture

Firstly, import the numerical dummy and car together, which is exact to the first method, then use the "Dummy Positioning tab" in the LS-PrePost to determine the right coordinate position of the simulation posture (right front of the car bumper with 3 orientations: 0°, 45°, 90°). Then, try to remember it and re-open the numerical dummy file. After that, save and replace the old file with the new dummy positioned one, following the process as shown in Fig. 10.

1.8 Motorcycle Model Testing

To test the operation of the motorcycle model in this paper, we simulate a collision with a passenger car. The crash test model is designed as shown in Fig. 11. In this case, the car is traveling at 20 km/h and the motorcycle is traveling at 10 km/h. The collision occurred on the left side of the car, with a collision percentage of 30%. When running the model analysis, errors about negative solid elements and velocities occur. After fixing the above errors, the model works normally and the simulation results are shown in Figs. 12, 13, 14 and 15.

a. Top view b. Side view

Fig. 11 Frontal impact car to motorcyclist test model

Fig. 12 The motorcycle stress (Pa)

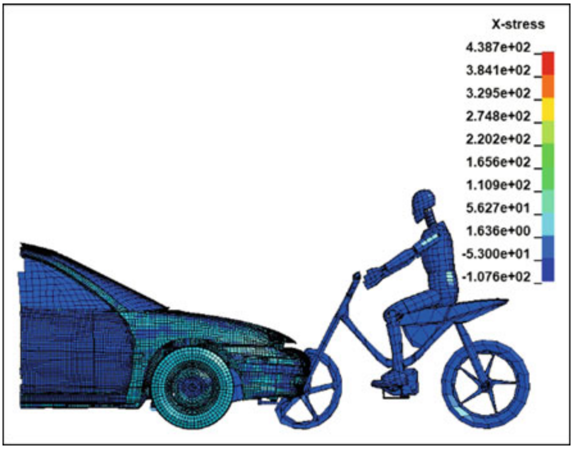
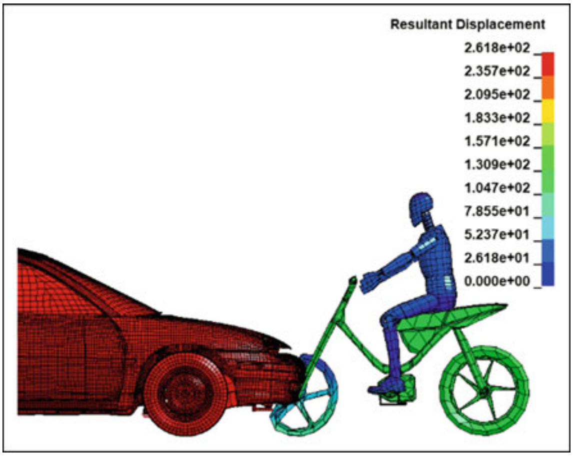


Fig. 13 The resultant displacement of motorcycle model (mm)



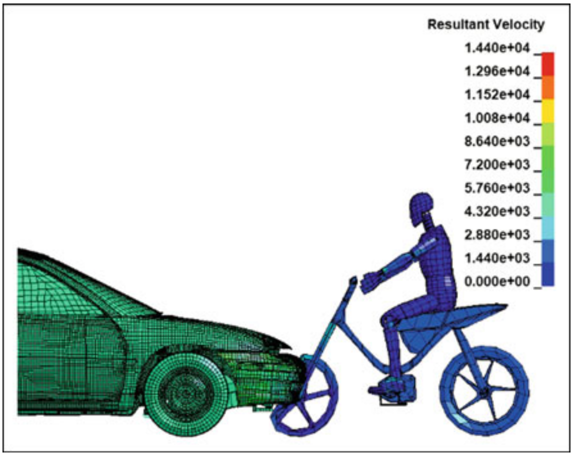


Fig. 14 The resultant velocity of motorcycle model (m/s)

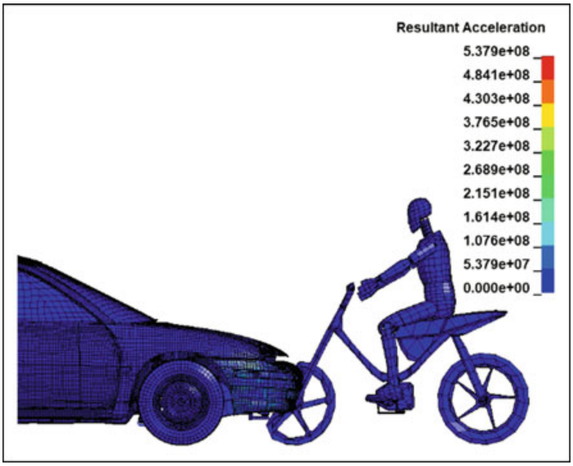


Fig. 15 The resultant acceleration of motorcycle model (m/s^2)

Simulation results show that when a collision occurs between a motorcycle and a car, the front part of the motorcycle is deformed, especially the front wheel and steering axle with the front shock absorber system. The stress is concentrated on the motorcycle wheel as shown in Fig. 12. The displacement of the model depends on the traveling speed of the motorcycle and car. Therefore, when the vehicle collides at a high speed, the vehicle will move larger, as shown in Fig. 13. The speed at which the two cars collide also changes. Because the car moves at a higher speed, the simulation results are part of the simulation results shown larger through color, as shown in Fig. 14. Due to the impact energy absorption deformation of the wheel and the front bumper of the car, the acceleration generated at impact is small, as shown in Fig. 15.

2 Conclusions

In this paper, a complete motorcycle model has been built that can be used to simulate collisions between motorcyclists and other vehicles such as cars, buses, trucks, pedestrians, and other motorcyclists. The detailed design process of the motorcycle model as well as the construction of the collision model is also given in the section of the article. Based on the simulation results, we can predict the injuries for motorcyclists, or we can improve the motorcycle's frame to improve safety in collisions between motorcycles and other traffic vehicles.

However, due to time and cost constraints, testing the accuracy of the motorcycle model has not been done. Therefore, the accuracy of simulation results has not been tested experimentally. The further research of this paper is to test the actual motorcycle model compared to the experiment to evaluate the accuracy of the model as well as the simulation results.

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