A Study on The Effects of Natural-Rubber and Concrete Panel Railroad Crossing Using Finite Element Method

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Abstract.

Thailand has a railway system with more than 2,500 railroad crossings, and these railroad crossings are generally made of concrete. The truck will reduce speed during passing through to avoid strong vibrations. The material used for comparison with concrete in this research is a rubber compound with a strength additive to absorb the vibration. The chemical composition of the rubber compound is Chloroprene Rubber (CR) 75% and Natural rubber (NR) 25% blended with additives such as carbon black (CB), magnesium oxide (MgO), and sulfur (S8). This research compares the effect on quarter- car models of a truck under dynamic load conditions using the finite element method. The analysis is divided into two steps, as follows: In the first step we applied load, that is unsprung mass and sprung mass of the model, which was obtained from the State Railway of Thailand, and in the second step we set the velocity are 10 km/hr, 20km/hr, 30 km/hr to this quarter-car model. The analyzed results at 10 km/hr, which is the average speed of a vehicle moving through a railroad crossing, showed that the max y-axis displacements of sprung mass when a truck passes through rubber and concrete panels are 11.83 mm,14.265 mm. the max y-axis displacements of unsprung mass are 14.01 mm,21.8401 mm. and the internal spring forces are -26,611 N and -29,897 N, respectively but when the truck's velocity increases the rubber panels are more deflated than the concrete panel resulting in the spring force increasing more than the concrete panel.

Keywords. car suspensions systems, quarter-car model, finite element method, hyperelastic material, compound rubber.

1. INTRODUCTION

Thailand is the world's number one primary processing rubber producer and exporter because Thai rubber has high quality and is recognized worldwide. Currently, Thailand has weaknesses or problems with the rubber industry, such as Thailand still relies mainly on rubber exports. when the global economy slows down, it will affect exports to the main markets. The volatility of raw rubber prices is beyond control. and many countries, especially Cambodia-Laos-Myanmar- Vietnam (CLMV) countries, have started planting more rubber cause the world rubber supply exceeds the demand. Therefore, Thailand must support and promote to use of rubber in the country. Including value-added rubber processing, which will help increase income for farmers.

The railway industry is growing due to investment in rail development in Thailand. That is developing a long-distance railway network from single-way to double-track, covering 47 provinces. So that in the future, the double-track railway will increase to 3,157 kilometers. Currently, there are more than 2,500 railway crossings across the country made of concrete. Therefore, cracking is a disadvantage because concrete is not resistant to repetitive loads, and concrete is a hard and brittle material. When the vehicle passed through the railroad crossing, there was a vibration causing a reduction in driving comfort and loud noise so that the car would reduce speed. All these reasons lead to accidents and cost the repair budget.

For this reason, this research used rubber compounds as an excellent alternative to shocking, and withstand repetitive loads. so the rubber can absorb shock. we study on effects of the Quarter-car model of a truck, which divide the analysis into two steps, that are assigning loads and setting velocity to pass through a railroad crossing for analyzing the y-axis displacement of unsprung mass, the y-axis displacement of the sprung mass, and the internal spring force for comparison between the rubber panel and the concrete panel. If the research is successful, the rubber panel can use instead of the concrete panel. That will result in the value of the domestic rubber industry has increased, designed and produced by Thai companies for value-added rubber processing, which will increase revenue for rubber farmers. and there are also promoting the use of rubber in Thailand.

2. METHODOLOGY

2.1. Quarter-Car Model

In order to study the effect of variables in the suspension system of trucks, a quarter-car model is a model that considers only one of the four corners of the car. It is the most widely used model because it has two degrees of freedom, which is easy to calculate because this model consists of only two equations of motion. which is shown in Fig. 1. A quarter-car model is used for this research. The model is determined that the unsprung mass has a mass equal to m_1, which consists of the mass of the wheel and axle. which is in contact with the rubber pad which has the function of the rubber pad as if there was a spring with the spring stiffness coefficient equal to k_r. The rubber panel has a spring stiffness coefficient that varies with each position. Then, the sprung mass is equal to m_2 , which consists of the mass of the vehicle body and the weight of the driver. which compares the operation of the truck's suspension system as if be spring and a shock absorber with a spring stiffness coefficient and the damping coefficient of the damper were k_2 and c_2, respectively. Let m_1 , m_2 be a rigid body to make it easier to calculate. And we don't consider the deformation of vehicle body, wheel, axle and tire Therefore, if the tire is a rigid body, we do not need to consider the spring stiffness coefficient and the damping coefficient of the tire in this research.

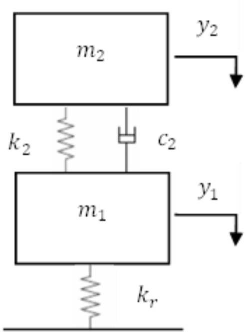

Figure 1 The quarter-car model of the vehicle.

The parameters of the quarter-car model for this research are shown in table 1.

Table 1 The vehicle system parameters for the quarter-car model

Sprung mass	m_2	2250 kg
Unsprung mass	m_1	320 kg
Spring stiffness	k_2	160 kN/m
Damping coefficient	c_2	1500 N_s/m
Rubber pad stiffness	k_r	Variable according to each position of the rubber panel

The mathematical model for the motion of the sprung mass (m_2) and the unsprung mass. (m_1) as shown in Fig. 2. and Fig. 3, respectively.

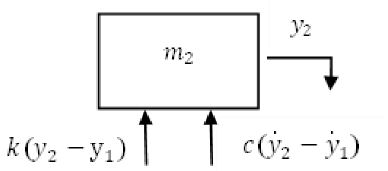

Figure 2 Free Body Diagram of mass m_2.

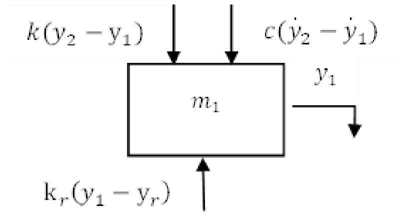

Figure 3 Free Body Diagram of mass m_1.

The purpose of the modeling was to study the y-axis displacement of the sprung mass and the unsprung mass, and the forces acting on the springs to study the effects of the truck suspension when the truck passed through rubber and concrete panel.

2.2. Material Propperties

Initially, we must determine material properties. The compound rubber has been researched and developed a formula to absorb the impact, this rubber panel composition is given in Table 2.

Table 2 Chemical composition of rubber

Ingredient	CR/NR ratio	carbon black	magnesium oxide	sulfur
Composition	75/25	60 phr	1 phr	1 phr

The properties of hyperelastic rubber use Yeoh's model to be considered in this research. The mechanical properties are obtained from the curve fitting value of the tensile test data. As shown in Fig. 4.

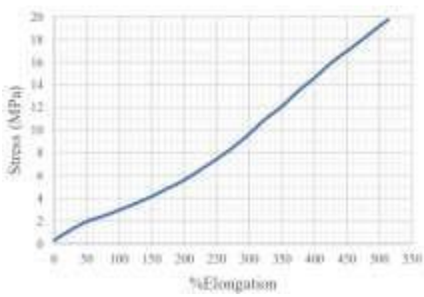

Fig. 4. Tensile test result of rubber.

From the curve fitting process using ANSYS, the Yeoh 3rd order model parameters are C_{10} = 82.595 x 10^5 Pa, C_{20} =15.303 x 10^4 Pa and C_{30} = -54.453 Pa, this constitutive model is given in equation (1).

$$W = C_{10}(I_1 - 3) + C_{20}(I_1 - 3)^2 + C_{30}(I_1 - 3)^3 \quad (1)$$

The components of the model used are shown in fig 4. and mechanical properties of other materials are shown in Table 3.

Table 3 Chemical composition of rubber

material	Ultimate Tensile Strength (MPa)	Yield Strength (MPa)	Young's modulus (MPa)	Poisson' sratio
Structuralsteel	460	250	20,000	0.3
Concrete	5	0	40,000	0.18

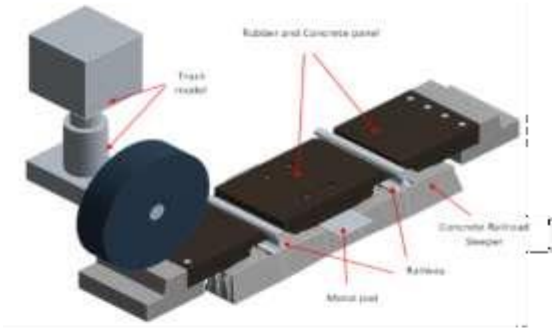

Figure 4 Model components.

2.3. Loading and Boundary condition

The finite element method analysis of 3D problems by ANSYS workbench program. We have divided the analysis into two steps: first step, Assign the load to the model. The load is coming from two parts that are 1. sprung mass. The load value is 22. 5 kN, 2. unsprung mass, The load value is 3.2 kN, and the second step. Assign the car to move on the -z-axis at 10km/hr, 20km/hr, and 30km/hr. as shown in fig 5.

The contact relationship of this model has cases that is 1. bonded contact, 2. Rough contact, 3. Frictional contact and 4. frictionless contact. The truck body and wheel on this model are assumed to be a rigid body. We set fixed support at the concrete sleeper, concrete support, and rail. The contact condition and fixed condition are shown in fig. 6 and 7. These settings were set to the same in both the concrete panel and the rubber panels to compare the effects of the truck suspension.

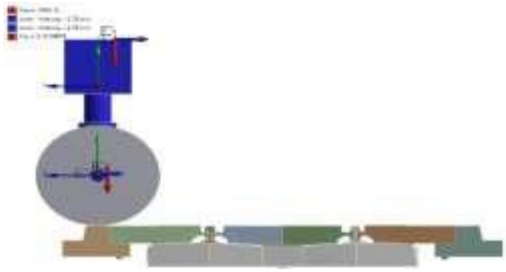

Figure 5 Loading condition

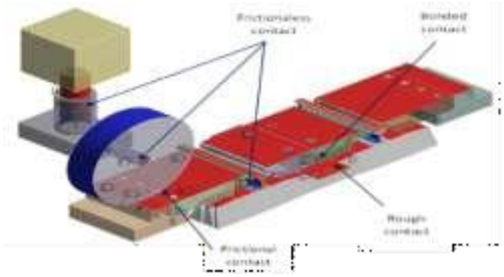

Figure 6 Contact condition.

Figure 7 Fixed condition.

3. NUMERICAL SIMULATION

The result is displayed in two steps. The first step is to balance the internal spring force between sprung mass and unsprung mass by setting a step time equal to 2 s, causing the system to enter equilibrium. Then the second step is to determine the duration relative to the speed of the truck, which is 0.98 s,0.491s, and 0.327s.

The result is as follows: the y-axis displacement of sprung mass, y-axis displacement of unsprung mass, and internal spring force at a speed of 10 km/hr are shown in fig 8,9,10, respectively.

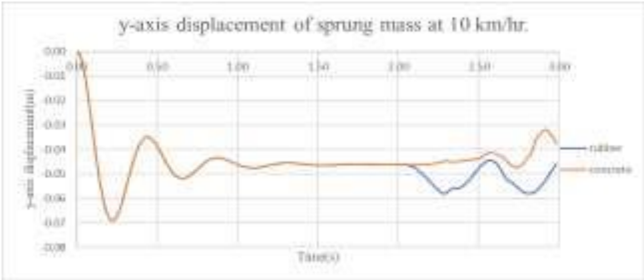

Figure 8 Y-axis displacement of sprung mass at 10 km/hr.

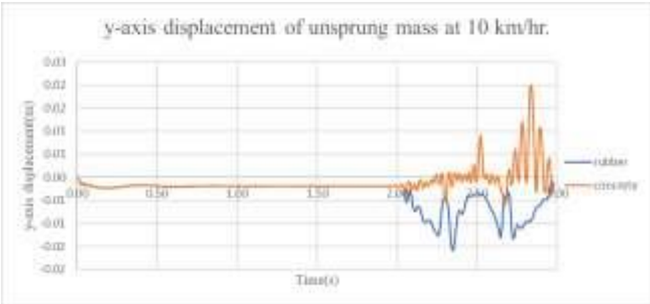

Figure 9 Y-axis displacement of unsprung mass at 10 km/hr

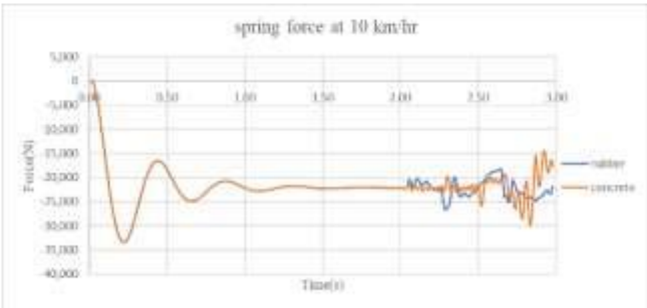

Figure 10 Spring force at 10 km/hr.

Then, we study on the effect of the spring force by analyzing the simulation results in the second step, which this step shows results when the truck passed through the Railroad Crossing in the -Z direction for a distance of 2.725 m. The results were compared between the Rubber Panel and the Concrete Panel at10km/hr, 20km/hr, and 30km/hr. shown in fig 11,12,13, respectively.

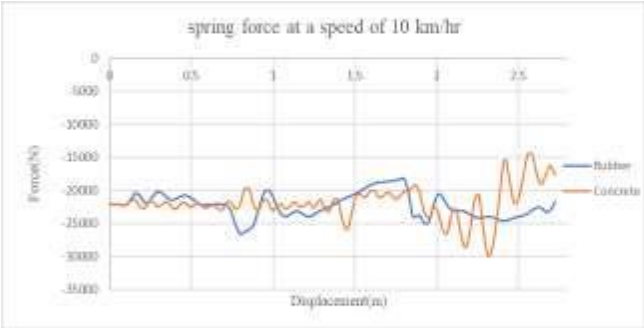

Figure 11 Spring force at 10 km/hr

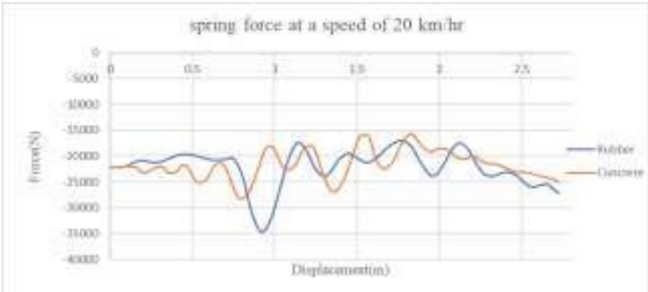

Figure 12 Spring force at 20 km/hr

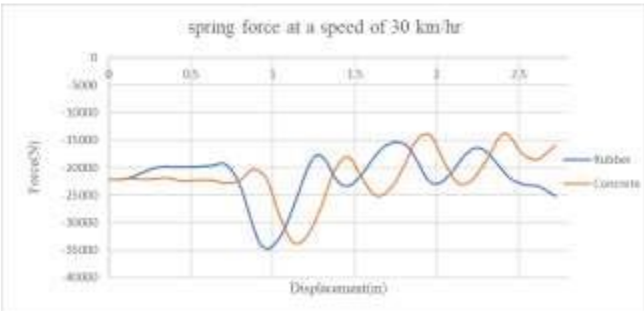

Figure 13 Spring force at 30 km/hr.

From the analysis results, the change in truck speed had a greater effect on the collapse of the rubber panels than the concrete panels. Therefore, the impact of the truck's suspension was analyzed, and compared the y-axis displacement of unsprung mass, and internal spring force when the truck passed through the rubber panel at all three speeds. shown in fig. 14,15, respectively.

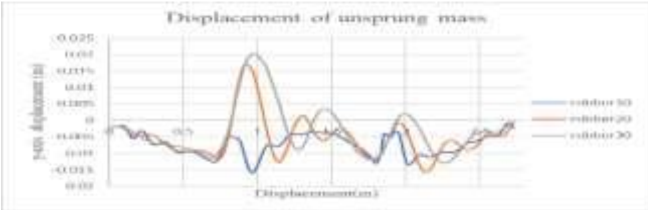

Figure 14 Y-axis displacement of unsprung mass (rubber panel).

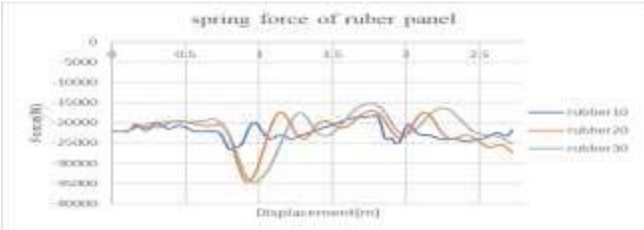

Figure 15 Y-axis displacement of sprung mass (rubber panel)

deformation of the external rubber panel shows as a sample because this part is most deflated shown in fig.16. and this reason resulting in the force in the spring is the most valuable when wheel impact with railway shown in fig.17.

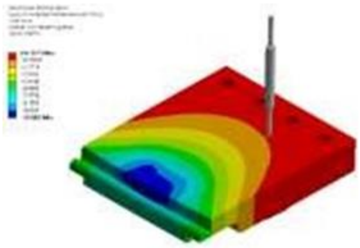

Figure 16 Deformation of external rubber panel

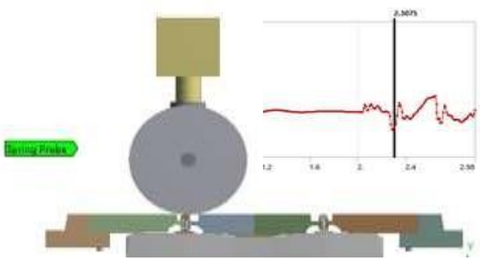

Figure 17 Max spring force at 10 km/hr.

4. CONCLUSIONS

According to the comparison results sample, at 10 km/hr as the average speed of a vehicle passing through Railroad Crossing has approximately 10 km/hr. The data values shown are the values added from the equilibrium point in step 1. as shown in table 4.

Table 4 The simulation result at a speed of 10 km/hr.

Results	Rubber panel	Concrete panel
Max y-axis displacement of sprung mass (mm)	11.83	14.265
Max y-axis displacement of unsprung mass (mm)	14.01	21.8401
Max spring force (N)	-26,611	-29,897

From the analysis results at 10 km/hr, when a truck passed through rubber panels. It appears that the two masses are moving down the collapsing of the rubber panels, which max displacement in the y-axis of the sprung mass and unsprung

mass collapse from the equilibrium point is 11.83 mm, 14.01mm. but when a truck passed through the concrete panel, unsprung masses impact the concrete panel, causing it to bounce back, which max displacement in the y-axis of the sprung mass and the unsprung mass bounce from the equilibrium point is 14.265 mm, 21.84 mm. It was concluded that the maximum displacement of both systems showed that the amplitude of the sprung mass, when passed through the concrete panel, was 20.58% higher than the rubber panel, and the unsprung mass of the concrete panel was 55.89% higher than the rubber panel.

Then considering the spring force when it passed through the rubber panel, the spring force is reduced, but when the truck at the neck of the rubber panel, which has the most collapses. Causing the wheels to impact the railway, and there is bounce. This is the reason why the force in the spring is increased to -26611N, but the concrete panel, when the truck passed through the railway, there is an impact with the concrete panel which is a hard material, resulting in the spring force increases and leads to vibration. The spring force of the system is up to -29897 N, so the spring force of the truck when it passed through the concrete panel was 55.89% higher than the rubber panel.

From the analysis, when considering the impact of the suspension system when the truck passes through the tire panel, it was found that As the truck's velocity increases, the tire panels are more deflated, resulting in the spring forces increase. so that should improve the neck of the rubber panel to collapse less

5. ACKNOWLEDGMENT

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