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A Computational Study Of Flexibelity And Vibration Analysis In Tire And Road Using Ansys Software 17.2

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ABSTRACT

The use of the car as a means of driving, Comfort, safety, and performance is the goal of the car design parameters. Tires are an important part that greatly affects the stability and performance of the vehicle. Because the tire is the only part of the vehicle that is directly related to the road surface. Both of them must be integrated to each other to get comfort, and good performance and safe when driving. Computerized simulation of mechanical dynamics is a useful tool to understand various processes of the occur on tires and roads. The simulation is conducted on radial tire type 195 / R 7514 tread block pattern and asphalt material as the path of road surface at the condition of car speeding with speed 0-50 km/h. Simulation condition is limited on constant loading, and the air pressure in the tire variation 28 Psi, 30 Psi, 32 Psi, 34 Psi, and 36 psi. Simulation data, the value of deflection and vibration is the biggest factor of damage and wear of tires and roads. And 30 Psi is the most appropriate tire pressure.

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1. INTRODUCTION

The tread of the tire which is in direct contact with the trajectory of the road surface greatly affects the traction between the tire and the road surface. The tread pattern affects tire performance. Tires and roads must be well integrated with each other. Otherwise it will cause a vehicle accident.

Tire grip is also influenced by the air pressure used, because this determines the amount of deflection of the tire when it comes into contact with the road surface. Insufficient air pressure in tires can result in excessive flexing as well as excess air pressure can affect tire life.

In relation to the road, tire grip is also influenced by road trajectory conditions, road geometric, type of road material, and environmental conditions. Based on the 1997 Highways Guidelines, the procedures for planning guidelines geometric intercity roads (TPGJAK), the classification of roads is divided into altery roads, collector roads and local roads. Generally, the types of road materials in Indonesia are asphalt roads, concrete roads, and bridge roads (steel).

Tires work by utilizing the frictional force of its surface with the road surface, this frictional force is called the grip. Grip is a consequence of molecular contact that can be measured at a very small level, around one-hundredth of a micron[4]. The grip gets bigger when the speed continues to increase or in other words accelerates.This grip causes the tire tread to wear out over time.

Uneven tire tread wear when traveling at high speeds can also cause bad vibrations. Bad vibration can affect the ability to drive, as well as safety and driving comfort.

At Rousse University, the Department of Automobiles, Tractors and Forklift trucks, analyzing the problem of pneumatic grip tires, has conducted experiments on various types and constructions of tires. The results show that the coefficient of grip with tires varies depending on tire load, air pressure in tires and wheel camber. The wheel camber causes a large change in the sliding grip coefficient of the wider tire, which has a smaller tapered tread curvature, due to a more significant change in the contact conditions between the road surface and the tape (the shape of the contact patch and pressure distribution).

Muhammad Nuh Hudawi Pasaribu (2017) conducted an experimental study to determine the effect of the roughness and slack of asphalt and concrete road surfaces on the grip coefficient, as well as determine the use of tire air pressure (Pban) which is safe when passing on asphalt road surfaces. The test results show the effect of road surface roughness ($\mu k = f(IRI)$ with every increase in speed (V) km/hour, there will be a decrease in the coefficient of kinetic friction. And the effect of road surface slack ($\mu k = f$ (dL) with an increase in vehicle speed (V) km/hour, there will be an increase in the coefficient of kinetic friction, and for safe use of tire air pressure when crossing on asphalt and concrete roads is 36 psi.

2. RESEARCH METHOD

2.1 Research Design Parameters

In this section we will discuss the methods and procedures of research work. To facilitate research on the phenomena experienced by tires and roads when tires cross the road surface, their causes and consequences, it is necessary to make research design parameters. The phenomenon of tire wear and the phenomenon that occurs on the road during tire rolling is analyzed focused on the total deformation that occurs in the tires and the road, as well as the vibrations that occur in the tires and the road. All of the above focus points are several factors that affect the amount of grip value due to contact between tires and the road. The grip function parameter is used to focus on what function variables are needed to analyze tire wear due to the grip between the tires and the road track. Based on the theory that has been described in chapter II.

a. Research input and output parameters

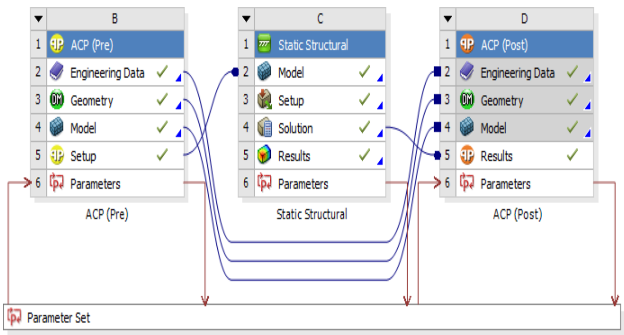

Figure 1. Parameter setting

b. Wheel design parameters

Table 1. Tire input parameters

Tire properties	Description /Value
Density	

Young's modulus	
Position ratio	
Bulk modulus (Pa)	
Shear modulus (Pa)	

Physical parameters that need to be considered in designing a tire are tire dimensions, tire model, tire tread model, and tire meshing model. Here are the tire models. The tires used are Bridgestone brand radial tires. The tire dimensions are 195/70R14 with a tread thickness of 1.8 mm with a block pattern. The following is the design of the tire model.

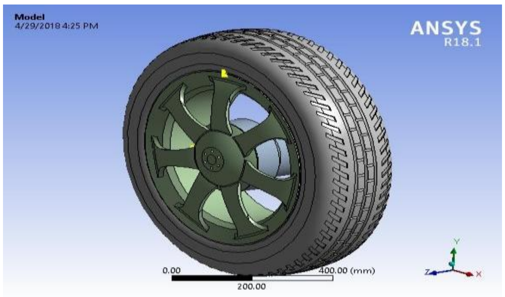

Figure 2. Radial tire model

c. Road Design Parameters

Table 2. Mechanical characteristics of asphalt roads

Data parameters	Value
Type of road material	
Young's modulus of road	
Thicknees	
Position Ratio	
Density	
Bulk modulus	
Shear modulus	

2.2 Preparation of Simulation Calculations.

There are several stages of preparation that need to be done to perform simulation calculations. Broadly speaking, these steps are the depiction of the 3D geometry of the tire and road, the formation of a mesh on each part of the geometry, preparation of the basic conditions and calculation methods, and finally the calculation iteration.

2.3 Preparation of Conditions and Calculation Methods.

At this stage all conditions and calculation methods are prepared and selected according to the desired type of simulation. In order to obtain satisfactory results the calculation conditions entered and the calculation method chosen must be appropriate.

3. RESULTS AND DISCUSSIONS

3.1 Simulation Analysis Results

Simulations are carried out on straight, dry road conditions, and the contours or roughness of the road surface are good and smooth with no potholes. Simulated tire air pressure (28, 30, 32, 34, 36,) Psi. Tires are accelerating at a speed of 0-50 km/h. Air pressure is made to vary so that later it can be assessed as safe/unsafe while driving.

The following will show some simulation results in the form of total deformation, stress distribution, and vibration on tires and roads. These results will be compared with the results of analytical and experimental calculations. Then the conclusion is obtained which is the end of this research.

The simulation results will be displayed in the form of pictures, tables and an explanation of the simulation results. In the simulation results there are differences in color contours. Different color contours indicate the value of a condition ranging from the lowest (dark blue contour) to the highest value (red contour).

a. Deformation simulation results on tires

The tire simulation results shown are the result of the amount of tire slack that occurs due to the influence of varying load, speed, air pressure. Deformation is a change in physical or chemical form due to rotational and radial loads experienced by an object. The rotational load here is equal to the rotational speed of the wheel (ω). The radial load is the vehicle's gravity (F). Deflection is a change in the shape of an object due to stress and strain. This slack test will see how much the elastic level of the inner tube receives the vehicle's load before it is damaged (wear).

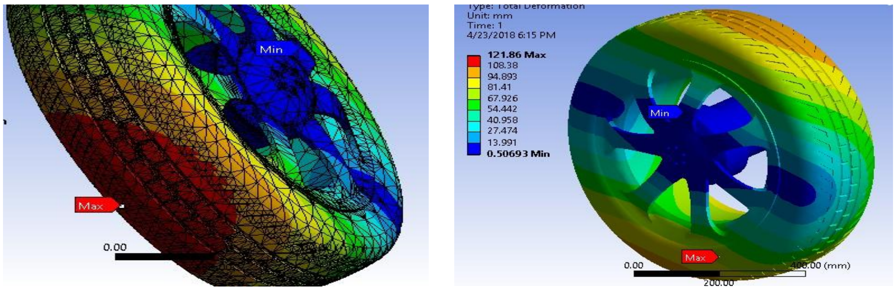

Figure 2. Total tire deformation speed 0-50 km/h

Figure 1 is the simulation result of total tire deformation with a speed of 0-50 km/h. The compressed air in the tire is 28 Psi (0.193053204 MPa) and the load is 3678.8 N. The difference in color contours is an indication of the large degree of deformation that occurs. The biggest deformation of the tire occurs at the bottom of the tire, namely the tire tread that is in direct contact with the asphalt road surface.

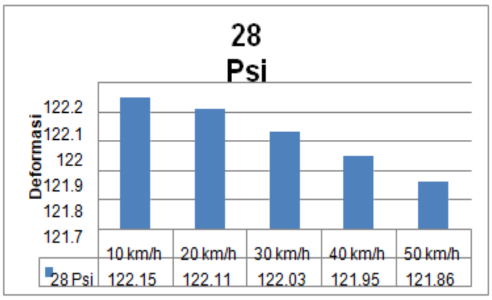

Figure 3. Graph of maximum tire deformation at a pressure of 28 Psi

The graph above explains that due to the loading of 3678.8 N and, a tire moving at a speed of 0-50 km/h the tire is deformed. At the air pressure of the tire containing 28 Psi the largest deformation occurred at the lowest speed, namely the speed of 10 km/h of 122.15 mm while the smallest deformation occurred at the speed of 50 km/h of 121.86 mm.

The difference in the value of the deformation due to acceleration is not large. Therefore, the tires do not immediately experience damage with certain trips. However, continuous use will result in wear and tear on the tire tread. Table 4.6 is the simulation result of the total tire deformation at the air pressure in the tire (28 Psi, 30 Psi, 32 Psi, 34 Psi, and 36 Psi) with a speed of 0-50 km/h.

Table 3. Results of total tire deformation on tire pressure variations

Velocity (km/h)	Pressure (Psi)	Max Deformation
	28	122.15 mm
	30	128.3 mm
10	32	128.66 mm
	34	131.66 mm
	36	134.46 mm
	28	122.11 mm
	30	128.27 mm
20	32	128.63 mm
	34	131.63 mm
	36	137.89 mm
	28	122.03 mm
	30	127.34 mm
30	32	128.57 mm
	34	131.57 mm
	36	138.22 mm
	28	121.95 mm
	30	125.31 mm
40	32	128.48 mm
	34	131.77 mm
	36	134.9 mm
	28	121.86 mm
	30	125.19 mm
50	32	128.38 mm
	34	131.41 mm
	36	134.22 mm

Comparison Result of Total Tire Deformation at Varied Pressure

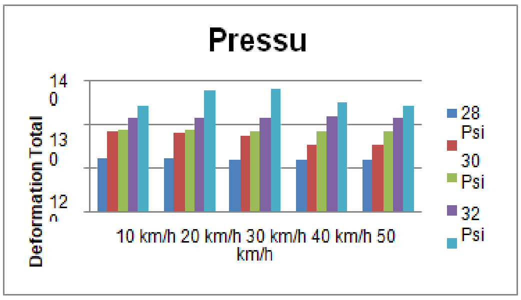

Figure 4. Graph of Deformation Vs Pressure

The greater the deformation, the greater the change in the shape of the material. This means that the slack that occurs in the tire tread that is in direct contact with the road surface will be wider; As a result, if it is continuously used, or not used at all, the tire tread will wear out faster. The average tire deformation value is 128 mm, but the high elasticity of the tire can keep the tire back in shape.

b. Equivalent stress simulation results on tires

Stress is the result of the ratio between the vertical forces acting on the cross-sectional area of an object. This stress simulation analysis on tires aims to see how the greatest stress occurs on the wheels when walking on the asphalt surface. The following is the result of the equivalent stress on a tire at a tire pressure of 36 Psi at a speed of 50 km/h.

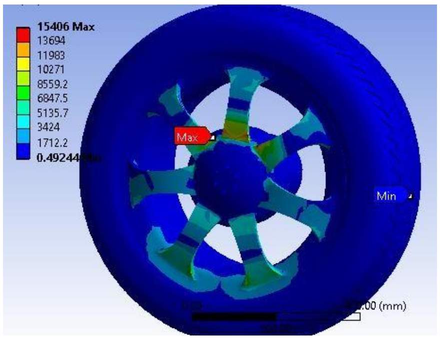

Figure 5. Equivalent stress on tires

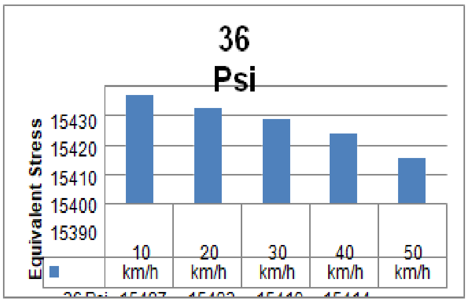

Figure 6. Graph of Equivalent stress on tires

The graph above explains that due to the loading of 3678.8 N (which is a vertical force) and the air pressure of the tire contains 36 Psi, with a rotational speed of 0-50 km/h. Tires also experience stress; The greatest stress occurs at a speed of 10 km/h, which is 15427 MPa. The smallest stress occurs at a speed of 50 km/h, which is 15406Mpa. From the simulation results, the greatest stress occurs on the wheel rim, which is directly related to the connecting axis of the tire to the vehicle.

c. Vibration simulation results on tires

1) 28 Psi . Vibration simulation result
   The following are 10 results of the display of eigen modes from tires using ansys 17.2 simulation. These results will show the various modes of vibration that occur in the tire and the natural frequency of the tire without any external force interference. After knowing the personal frequency, further simulation is carried out using the harmonic response to determine the elastic strain of the tire and the vibration phase.

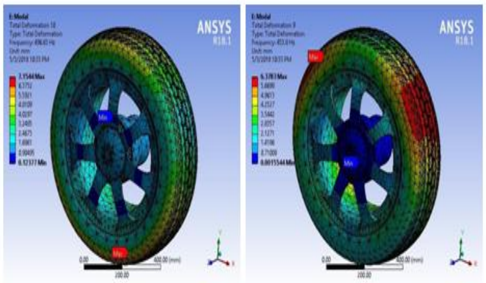

Figure 7. mode 10 and mode 9

In Figure 7, it can be seen that the frequency is 496.63 Hz, and this eigenmode 10 is located at the bottom of the tire tread (the max probe is red). From the condition, it is explained that the tires experience the greatest vibration in the tires that occur when the tires are in direct contact with the road surface. While the frequency in Figure 4.7 mode 9 is 453.8 Hz. This Eigenmode 9 shows the biggest point of vibration on the red max probe.

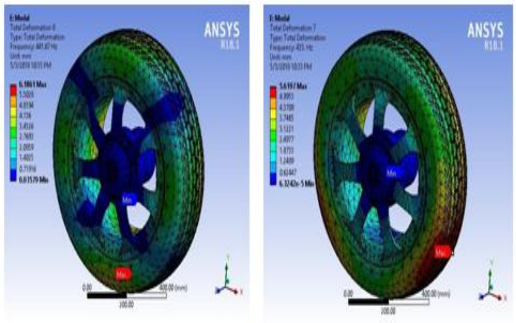

Figure 8. Mode 8 And Mode 7

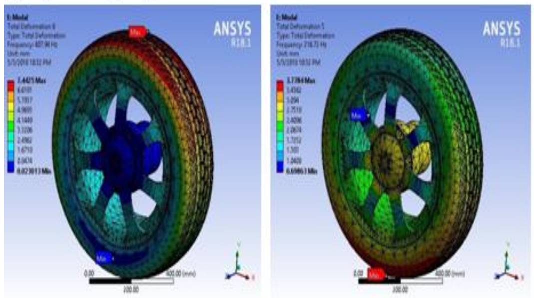

Figure 9. Mode 6 And Mode 5

In Figure 9 it can be seen that the max frequency is 407.94 Hz, and this eigenmode 6 is located on the top tire tread (the max probe is red). From the conditions explained that the tires experienced the greatest vibration at that point. While the frequency in Figure 4.11 mode 9 is worth 216.72 Hz. Eigenmode 5 is almost similar to eigenmode 10, which shows the biggest point of vibration on the red max probe.

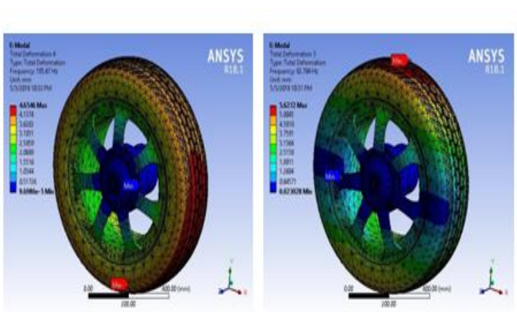

Figure 10. Mode 4 and Mode 3

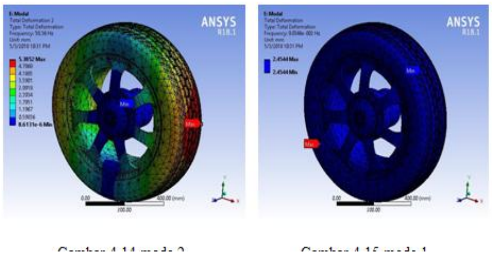

Figure 11. Mode 2 and Mode 1

In Figure 11 it can be seen that the max frequency is 58.36 Hz, and this eigenmode 2 is located on the side of the tire tread (the max probe is red). While the frequency in Figure 4.15 mode 1 is worth 2,454 Hz. Eigenmode 1 shows the biggest point of vibration on the red max probe. This is the condition just before the tire moves.

d. Deformation simulation results on Asphalt Jalan Road

The simulation results displayed are the results of total road deformation, road equivalent stress, and vibration on asphalt roads with constant loading longitudinally by 3678.8 N by the weight of a vehicle traveling at a speed of 0-50 km/h.

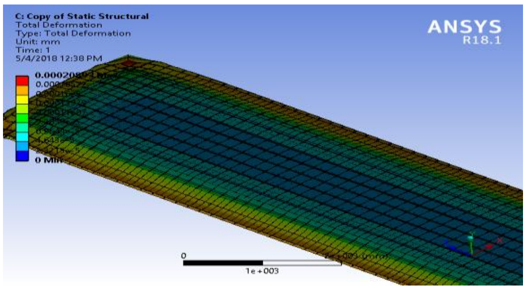

Figure 12. deformation of the top and bottom

In the picture above, it can be seen that the largest deformation occurs at the edge of the highway. The largest deformation value is 0.00028309 mm. Changes (flexibility) that occur in asphalt cannot be seen by the eye. Because the shrinkage that occurs is the size of a micron. However, the road that is continuously used will also experience wear and tear, until eventually the road is damaged.

e. Equivalent Stress Results on Asphalt Road

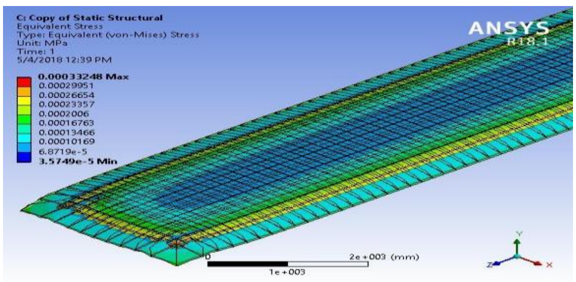

Figure 13. Lower Road Stress

3.2 Comparison of Simulation Results with Experimental Results

Although the calculation of slack and vibration analysis on tires and roads using the finite element method is a very powerful way to get results, we must still make comparisons with experimental data results to ensure the accuracy of the results obtained. Comparisons made only made of slack and vibration on the tires.

The percent error value may be much different because the simulation results assume that the tires are accelerating and the type of vibration experienced by the tires is free vibration (undamped vibration) and the experimental reality is free vibration (dampad vibration).

Table 4. Data from the measurement of tire tread area (slack) caused by tire air pressure.

P tire (psi)	Pavement		
	P(mm)	L (mm)	Atba(mm²)
28	148	140	20,720.00
30	145	137	19,865.00
32	142	134	19,028.00
34	137	129	17,673.00
36	134	126	16,884.00

4. CONCLUSION

Every object that has mass and elasticity must experience vibration and with the application of an external force (load and velocity) the object will experience deformation.

The simulation results prove that when given a load, with varying speed and air pressure in the tires; tires and roads experience deformation and vibration that affect the condition of tires and roads (experiencing tire damage or wear).

The use of 30 Psi pressure at a speed of 30 km / h for air pressure in the tires is the best choice to get the safest performance when crossing on the highway. The simulation results obtained are in accordance with the theoretical results, The results of the largest deformation occurred at a pressure of 36 Psi with a speed of 30 km/h. that is equal to 138.22 mm and the smallest deformation results occur at a pressure of 28 Psi with a speed of 50 km/h. that is equal to 121.86 mm.

The results of the largest equivalent tress occurred at a pressure of 36 Psi with a speed of 10 km/h. that is equal to 15427 MPa and the smallest Equivalent tress results occur at a pressure of 28 Psi with a speed of 50 km/h. that is equal to 12748 MPa. The type of vibration on this tire is the mass spring vibration type, The results of the largest tire vibration occurred at a frequency of 510 Hz and the smallest tire vibration occurred at a frequency of 62,406 Hz. While the biggest vibration on the road is at a frequency of 193.3 Hz and the smallest vibration is at a frequency of 191.75 Hz.

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