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Stress Investigation on the Rolling Tires across the Speed Bump Using Finite Element Method

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Abstract. The interaction between road surface and tire on a vehicle may strongly determine the vehicle's stability. This study was conducted to find out the stress distribution as a result of pressure on the tires rolling across the speed bumps. This study used Abaqus software to simulate the movement of the tire, which rolls across the speed bump to determine the stress distribution that may occur. The tire component material used was a full path rubber on a speed bump. For the boundary conditions of the study, it was assumed that the tires had load variations as much as 2 kN, 6 kN, 10 kN, as well as pressure variations as much as 17 Psi, 30 Psi, 40 Psi. The tires were then rolled 8 km/h crossing the speed bump. Modeling speed bumps also varied i.e. the first variation of speed bumps that have a height of 50 mm with a width of 250 mm, the second variation of height 75 mm with a width of 300 mm, and a third variation of height 100 mm with a width of 400 mm. The simulation was done by giving the tire pressures as much as 17 Psi, 30 Psi, 40 Psi and loads as much as 2 kN, 6 kN, 10 kN. Further, the tires were rolled three times. It was rolled crossing the first speed bump, the second, and the third, respectively. Results showed stress distribution's fig and graphs. From the analysis results and simulation, it was shown that the greater the load received by the tires, the higher stress they produced.

INTRODUCTION

Tire is an important part of ground vehicles. It is used to reduce trembling caused by road surface irregularities,

protect the wheels from wear and damage, and maintain the stability of the road and ground in order to increase the speed and ease of movement. Tire is one of the most important elements of a vehicle that is used to control the direction of a vehicle. Besides, the tire is also used as a substitute of the engine power, and system damping / vehicle suspension. Researches on the interaction between tires and road surface in a vehicle are considerably important, and it is closely related to the environment and safety riding issues. According to this phenomenon, a considerable number of scientific works had been conducted to explore physical phenomena that affect the mentioned interactions [1-8].

In this context, this paper presents a numerical method based on the finite element method by using ABAQUS software to predict the stress distribution caused by contact pressure on the tire that rolls across the speed bumps. Here, the difficulty levels can be seen from an attempt to extract the strain value as well as distribution profile. A new step is introduced to evaluate the stress distribution due to the tire contact pressure with the road.

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In this study, we use rubber for the tire material, table of material, and the tire elements which can be seen in the following table 1, table 2, and table 3. Further, the tire dimension, the carcass dimension, belt 1 and belt 2 are presented in Fig 1, as follows:

TABLE 1. Tire Materials

Material	**D1 (Mpa)**	**C10 (Mpa)**	**C01(Mpa)**	**Density**
Rubber	0.1	0. 8061	1.805	1400

TABLE 2. Table of Material

Material	**Elastic (Modulus elasticity)**	**Poisson ratio**	**Density**
Carcass	500	0.3	1200
Belt	172200	0.3	5900

TABLE3. The Tire Elements

Components	Element type	Number of elements
Tire	C3D8RH: An 8-node linear brick, hybrid, constant pressure, reduced integration, hourglass control.	1564 elements
Carcass	SFM3D4: A 4-node quadrilateral surface element.	768 elements
Belt 1&2	SFM3D4: A 4-node quadrilateral surface element.	BELT1=204 elements BELT2=210 elements
Road (Rigid)	R3D4: A 4-node 3-D bilinear rigid quadrilateral	1390 elements

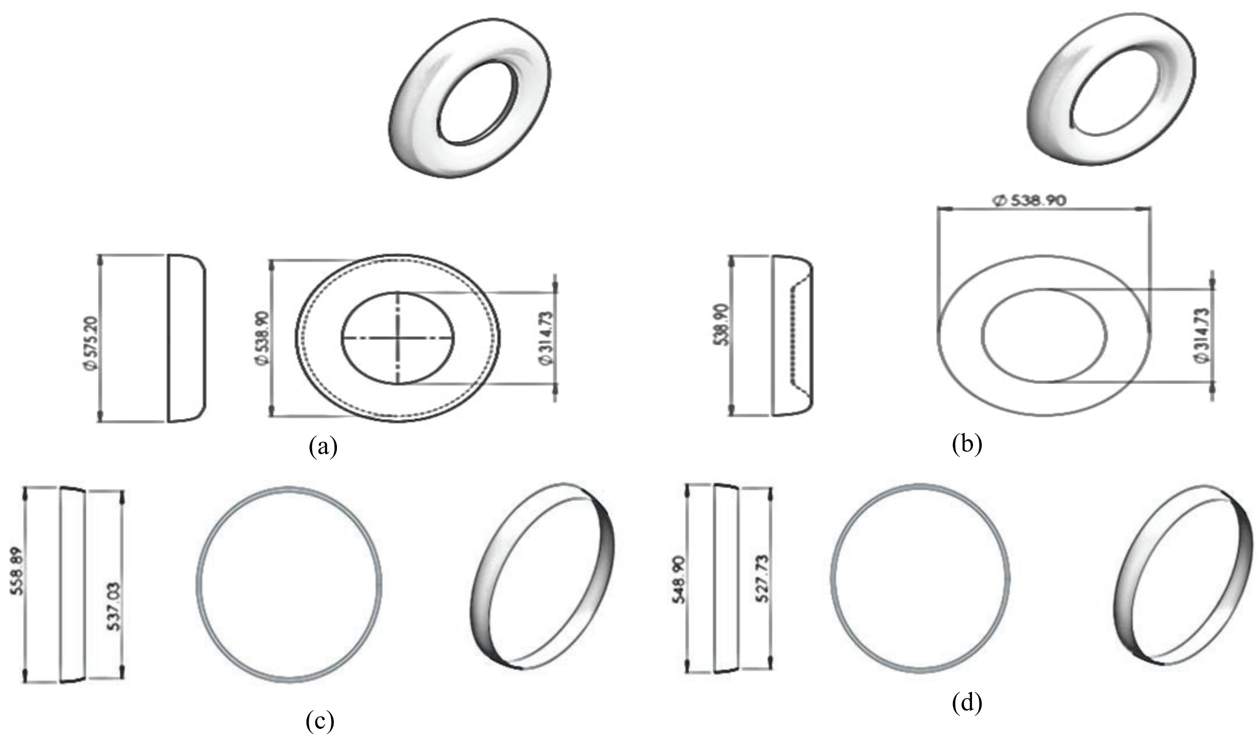


FIGURE 1. Computational Domain, (a) tire dimension, (b) carcass dimension, (c) the belt 1 dimension, (d) the belt 2 dimensions

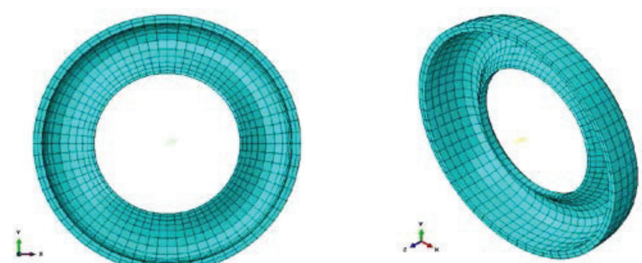
In this study, the finite element method is developed by using ABAQUS software. The results of this study contribute to a better understanding for failure analysis related to the stress distribution of tires.

THE RESEARCH METHODS

Research on the impact of speed bumps towards stress on the tire was conducted by using Finite Element Method. The simulation was initiated by modeling the tire by using Solidworks 2013 software as presented in Figure 2. Further, the modeling tire was converted into ABAQUS 2013 software to be analyzed by giving air pressure and loads to the tire. The tire would be rolled afterward to find out the stress value occurred on the tire.

The simulation steps can be seen from the following procedure:

1. The tire was modeled in a half piece by using Solidworks 2013 software. The model will be later converted by using Abaqus software, as presented in Fig 5, as follows : (b)



(a) (b)

FIGURE 2. Messing the tires by using solidworks software (a) the front look (b) tire isometry

2. The speed bumps in this simulation were created by using ABAQUS software with three different variations of speed bumps. The first variation of speed bumps that have a height of 50 mm with a width of 250 mm, the second variation of height 75 mm with a width of 300 mm, and the third variation of height 100 mm with a width of 400 mm. The results can be seen from the following Fig3:

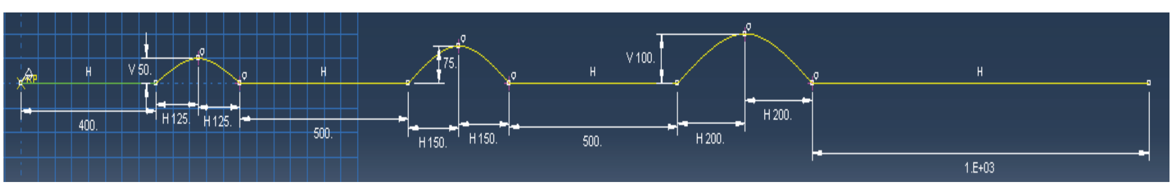


FIGURE 3. The speed bump modelling

3. The tire component assembly was done as the initial step before conducting the simulation. It can be seen from Fig4, as follows:

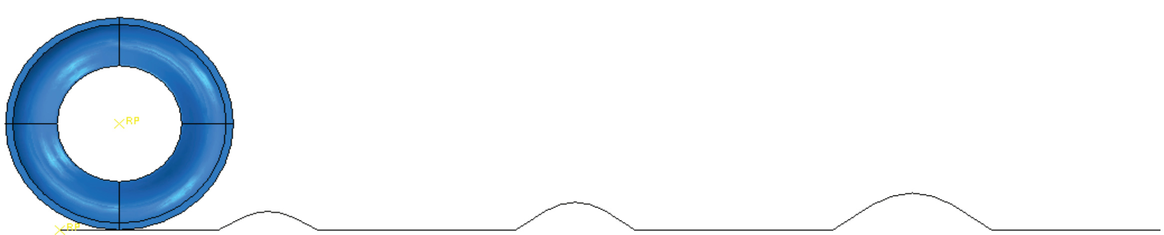
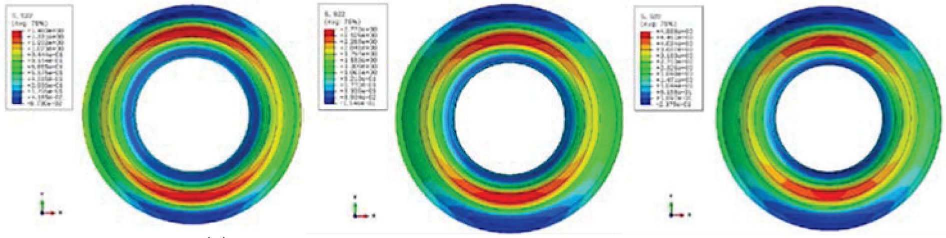


FIGURE 4. Tire component assembly with the modeling speed bumps on the road

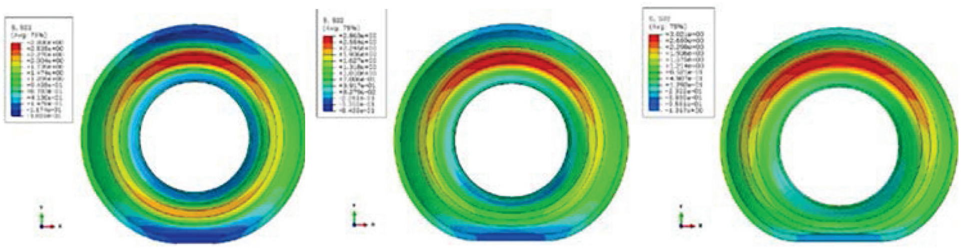
4. Air pressure was given to the tire with pressure variations as much as 17 Psi, 30 Psi and 40 Psi as shown in Fig5:



(a) (b) (c)

FIGURE 5. Giving the tire pressure (a) 17 Psi, (b) 30 Psi, (c) 40 Psi

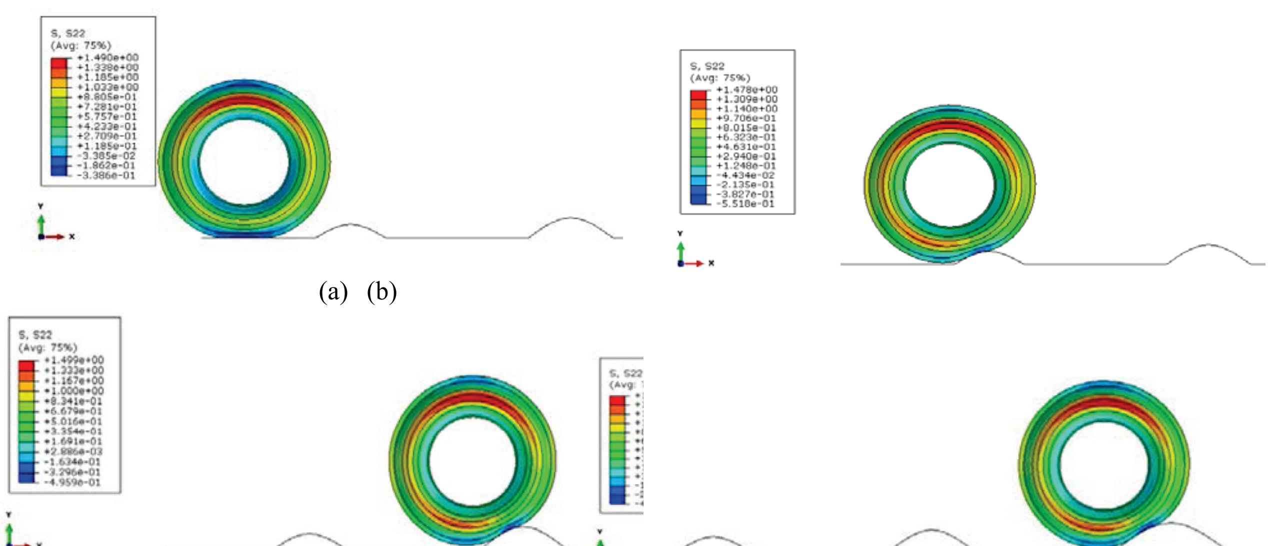
5. The load was given to the tire with various loads as much as 2 KN, 6 KN, 10 KN. It is presented in Fig6, as follows:



(a) (b) (c)

FIGURE 6. The pressured tires are given with loads as much as (a) 2 KN (b) 6 KN (c) 10 KN

6. Giving rolling force on tires with V= 8 Km/h, rolling across the speed bumps with three variations. The first 6. Giving rolling force on tires with V= 8 Km/h, rolling across the speed bumps with three variations. The first variation of speed bumps that have a height of 50 mm with a width of 250 mm, the second variation height is 75 mm with a width of 300 mm, and the third variation height is 100 mm with a width of 400 mm, with loads of 2 KN, KN 6, 10 KN on the tires with a pressure of 17 Psi, 30 Psi, and 40 Psi, respectively, as shown inFig7:



(a) (b)

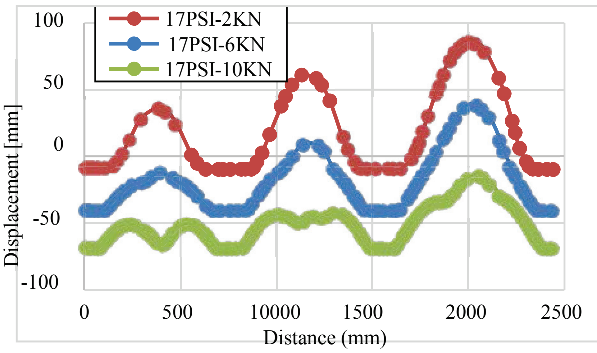
(c) (d)

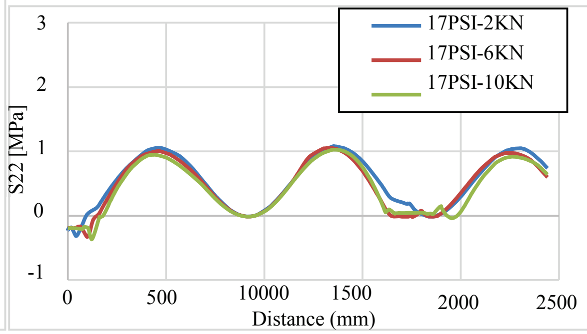
FIGURE 7. Tire simulation with pressure variations of 17 Psi, 30 Psi, 40 Psi and load variations of 2 KN, 6 KN, 10

KN, rolling across varied speed bumps (a) before crossing the speed bumps, (b) speed bump with a height of 50 mm and a width of 250 mm (c) speed bump with a height of 75 mm, a width of 300 mm, (d) speed bump with a height of 100 mm and a width of 400 mm.

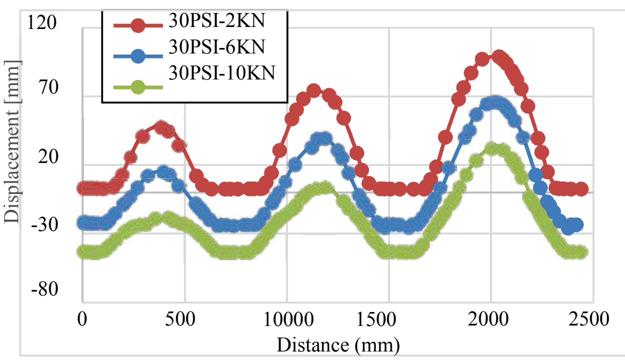
SIMULATION RESULTS

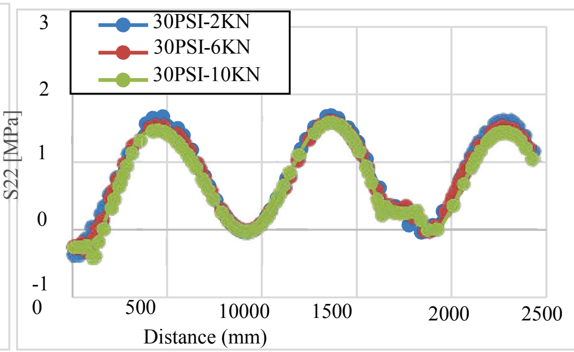
The simulation results show the impact of the speed bump shape towards the stress occurs on the tires. The results themselves are presented in Fig8, as follows:



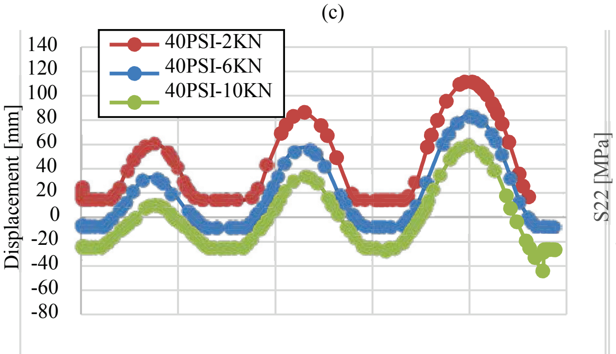


(a) (b)





(c) (d)



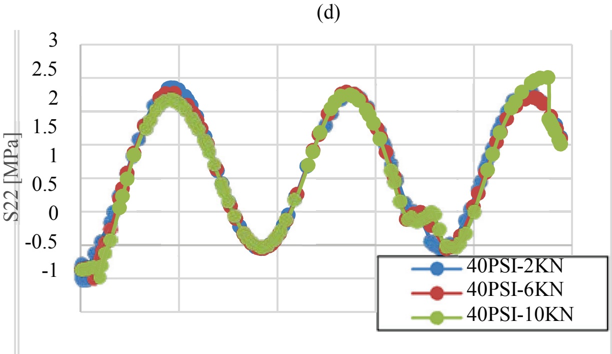


FIGURE 8. Simulation result graph (a) relationship between displacement and distance with a pressure of 17 Psi and loads of 2KN, 6 KN, 10 KN, (b) relationship between s22 (the stress) between distance with a pressure 17 Psi and load 2 KN, 6 KN, 10 KN, (c) relationship between displacement and distance with a pressure of 30 Psi and loads of 2KN, 6 KN, 10 KN, (d) relationship between displacement and distance with a pressure of 40 Psi and loads of 2 KN, 6 KN, 10 KN, (f) relationship between s22 (the stress) between distance and a pressure of 40 Psi and loads of 2 KN, 6 KN, 10 KN.

7. From the graphs in Fig8 (a) and 8 (b), it can be explained that in air pressure of 17 Psi, the highest stress distribution occurred when it is given a load of 2 KN and crossed the first variation of speed bump, 50 mm height and 250 mm width. The highest displacement also occurs on a load of 2KN when the tires are rolling across the third variation speed bump with a height of 100 mm and a width of 400 mm.
8. From the Fig8 (c) and 8 (d), it can be seen that on the air pressure of 30 Psi, the highest stress s22 occurs when it is loaded with 2 KN load and it rolls across the first variation speed bump of 50 mm height and 250 mm width. The highest displacement also occurs with vehicle of 2 KN load when it rolls across the third variation speed bump of 100 mm height and 400 mm width.
9. From the Fig8 (e) and 8 (f), it can be seen that when the air pressure is on 40 Psi, the highest stress distribution s22 occurs when it is loaded with 10 KN load, when the tires are rolling across the speed bump the third variation bump with a height of 100 mm height and a width of 400 mm. Meanwhile, the highest displacement occurs when it is loaded with 2 KN load and the tires are rolling across the third variation speed bump of 100 mm height and 400 mm width.

CONCLUSION

It can be concluded that the effect was shown in displacement graph and stress s22 every time the tire crossed the speed bumps. From the graph, it was shown that the speed bump gave an impact towards displacement and stress s22 of the tires. Further, we may see when was the best condition of the tire that it could respond better towards the speed bump. On the graph in fig8, it was shown that the highest displacement occurred when tire pressure was 40 Psi with a load of 2 KN, and it crossed the third variation speed bump with a eight of 100 mm and a width of 400 mm for 111.266 mm and the length of distance 1976.93 mm. For this, the lowest displacement of the tires was 17 Psi with a load of 10 KN before it rolled crossing the speed bump -68.991 mm for the distance of 1576.54 mm. The highest stress distribution occurred when the tire was loaded with 40 Psi load for 2.50484 Mpa for the distance of 2378.14 mm. Here, the lowest stress distribution occurred when the tire was 40 Psi with 2 KN load before it rolled crossing the speed bump for -0.545856 Mpa with the distance of 8,64111mm. Therefore, it is suggested that to roll crossing various measurement of speed bumps, the air pressure is supposed to be 30 Psi. In this condition, the displacement with 10 KN load still responds well, which is 43.7246 mm while the stress distribution s22 is considerably not too high in 1.57526 Mpa than using the air pressure of 40 Psi.

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