Novateur Publication's
International Journal of Innovation in Engineering, Research and Technology [IJIERT]
ICITDCEME'15 Conference Proceedings
ISSN No - 2394-3696

ANALYSIS OF VERTICAL STIFFNESS OF PASSENGER CAR TIRE AT DIFFERENT PRESSURE USING FE MODEL

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ABSTRACT
The most critical factor for maximizing tire life and minimizing the chance of tire failure is maintaining the proper inflation pressure for given tire size and load. The objective of this paper is to optimization of vertical stiffness and implement it do increase capacity of tire normal force and then improve vehicle stability. The stiffness of passenger car tire P135/70R12 in the radial direction has been measured. This information is based on the measurement of single tire at inflation pressure [1.3, 1.7, 2, 2.4 and 2.7bar] and vertical load range [400,500,600,700 and 800kg]
A finite element analysis of tire using Ansys is used to analyze the behavior of stationary tire vertically loaded against a stiff horizontal surface at different load, under static condition

KEYWORDS: Tire vertical stiffness, inflation pressure, load-deflection characteristics, ANSYS software

INTRODUCTION
Vehicle stability includes the holding ability between tire and road and anti roller ability. Automobile control acceleration and braking occur through the tires and their contact on the road surface. The tires must be large and strong, enough to support the vehicle on road. The tire must absorb, by deflecting, part of the shock from road irregularities. The objective is to determine the vertical stiffness of a P135/70R12 passenger car drive tire using the Load Deflection method. This measurement is to establish value of tire stiffness which used for vehicle simulation and to observe the way this value changed under different conditions.
The tire has a plain tread with two circumferential grooves. it is constructed from a number of rubber components and reinforced rubber composites. The effect of the pressure in the tires to the size of the surface area of the tire tread contact with the road, it has been proved that the pressure variation inside the tire has a significant effect on the change of stress distribution on the surface of the contact with the ground [1]. They conducted experiment on the test setup of different tires under static condition. The result was used to determine directional tire stiffness and the surface area of the tire contact with the ground depending on the pressure inside the tire and the load with the increasing in pressure in the tire contact area with the ground is reduced.[1]
A small radial ply drive tire was chosen for rolling and non-rolling test at different inflation pressure The maximum change in area about 70% was observed in the range of pressure from 1 bar to about 2 bar. Deflection.Taylor (1996) examined potential equations to describe the relationship between load and deflection. Stiffness obtained from non-rolling and rolling free vibration tests were regressed as linear functions of equilibrium. Hysteresis in the tire is likely causing the tire to appear stiffer during free vibration[2].
Analysis of tire tube with fluid dynamic properties and simulation using CFD tools. The various properties taken into account was static pressure, dynamic pressure and radial velocity.[3] The stiffness of the tire when it is stationary is usually greater than when it is rolling. Stationary tire stiffness is more dependent other factor such as amplitude and frequency than rolling tire stiffness [4].
The quasi-static behavior stationary automobile tire vertically loaded against a horizontal surface was successfully investigated using LS-DYNA3D simulation. The simulation result and the experimental data both suggest, for load between 1KN and 5KN and approximately linear relationship between load and contact patch length and non linear relation ship between the load and contact patch width. [5] static and dynamic tire test was conducted the tire carcass shape was measured and the footprint dimension of the tire were determined at various tire inflation pressure and normal loads using cleats with different dimensions the modal analysis was also determined the vibration mode and natural frequencies of the tires.[6,8]
Tire normal force of a vehicle equipped with a variable stiffness and damping (VSVD) suspension system is studied via numerical simulation. For analytical method used governing equation of the suspension system, and calculate the stiffness and damping coefficient. The adjustment of variable stiffness and damping behavior is feasible by the use of MR damper because MR damper is capable to change damping coefficient rapidly. [8]

FINITE ELEMENT MODELING OF TIRES

2.1 PROCEDURE IN FINITE ELEMENT ANALYSIS

The complete FE analysis procedure can be divided into the following six stages.

A. PROBLEM DEFINITION

It is necessary to understand about the problem being simulated in order to accurately define it. This includes geometry details, fluid properties, and initial conditions.

B. GEOMETRY CREATION

The geometry of the tire is created using CATIA 3D modeling software. Usually, 2-D sketches are first drawn and 3-D tools are then used to generate the full geometry.

C. MESHING

In this stage the 3D geometry of tire is import in analysis software ANSYS. Complete geometry is divided into sufficiently small discrete cells, the distribution of which determines the positions where the load variables are to be applied and stored. Variable gradients are generally more accurately calculated on a fine mesh than on a coarse one.

D. MATERIAL SPECIFICATION

Material specification involves the physical properties of tire component such as material, Young's modulus of elasticity, Poisons ratio, Density etc.

E. CALCULATION OF THE NUMERICAL SOLUTION

When all the information required for the simulation has been specified, the ANSYS software performs iterative calculations to arrive at a solution to the numerical equations representing the variable.

F. RESULT ANALYSIS

Obtained the solution, analyze the results in order to check that the solution is satisfactory and to determine the optimize value.

2.2 SIMULATION METHODOLOGIES

The geometry of the tire is created using CATIA 3D modeling software as shown in Fig.4.2, is investigated. The geometry of the tire considered is that of P135/70R12. The pneumatic tire is assumed to be fixed on the hub and vertical load is applied. The tire consists of one layer of carcass, one layer of steel belts, and the outer rubber.

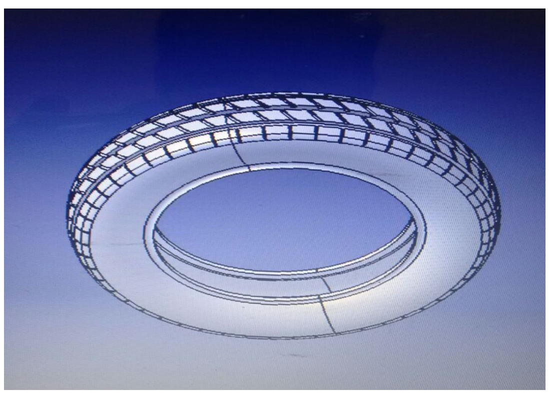


Fig.1 3D tire Geometry

Table.1 The of Specification of radial tire P135/70/R12

Sr. No.	Specification	Millimeter
1	Section width	135
2	Aspect ratio	70
3	Rim Diameter	300
4	Outer diameter	494
5	Height	94.5
6	Circumference	1551

For simplifying the problem, some reasonable assumptions are made for the simulations:
1. Assume that tires are consisted of rubber, carcass and steel belt.
2. Rubber is assumed to be isotropic, homogeneous, and fully cured in any part of the tire, and has hyper-elastic behavior through the entire temperature range.
3. The steel belt is elastic, isotropic, and homogeneous.
4. The road is assumed to be a rigid.
5. Neglecting the fluctuation of friction between the road and tire, and assume the friction coefficient between the road and tire is a constant: 0.1 material properties each layer as shown in table 2 and 3.

Table 2.Material properties of rubber

Material	Young's modulus of elasticity (MPa)	Poisons ratio	Density
Rubber	18	0.49	1.18e03

Table 3.Material properties of cord layer

Properties	Steel belt	carcass
Young's modulus of elasticity (MPa)	27317.708	1196.15
Poisons ratio	0.44	0.45
Modulus of rigidity(MPa)	4.16	4.43
Density(kg/m^3)	2.50E03	1.15E03
Angle (degree)	70	0

A radial tire shown in fig.2 is investigated, in which it is kept on fixed horizontal support assumed as ground. The geometry of tire considered is that of P135/70R12. Tire received all degrees of freedom except for the vertical displacement.

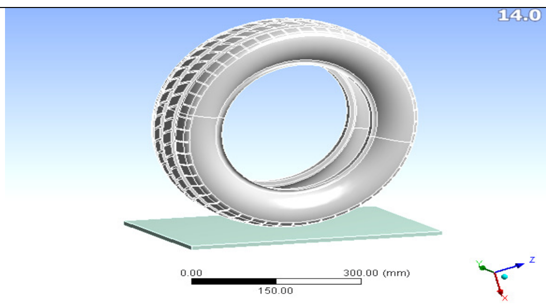


Fig.2.Model of the tire and the ground

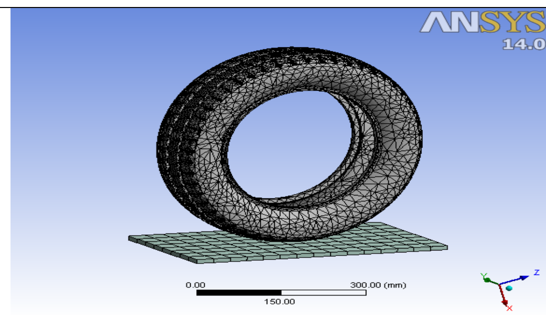


Fig.3 Meshing of tire

The model takes into account the occurrence of tire reinforcement described. They are modeling in the form of finite element type "shell", embedded in solid elements solid The element is defined by eight nodes This element is having three degree of freedom i.e. UX,UY and UZ. For the radial tire P135/70R12, the total number of nodes taken is 7532 whereas the total number of elements comes out to be 34945. The Fig.3 represents the meshed tire

2.3 LOADING ANALYSIS

Different inflation pressures and loadings were simulated for obtaining the displacement without Rolling, which is a static analysis Steady-state results of displacements between road and tire under different conditions were obtained. Different loads were applied at the center of the tire, and inflation pressure was applied at the inner surface of the tire.
For determine the stiffness of tire at static condition load and pressure value

Table 4.load and pressure value

Load (kg)	400	500	600	700	800
Pressure (bar)	1.3	1.7	2	2.4	2.7

RESULTS AND DISCUSSION

3.1 FINITE ELEMENT ANALYSIS RESULT:

In the simulation the load is assumed to be the vertical (z-direction) reaction force generated at the tire and the deflection is assumed to be the corresponding vertical deflection. Different inflation pressures and loadings are simulated for obtaining the displacement. Different loads are applied at the center of the tire, and inflation pressure was applied at the inner surface of the tire. Fig.4 shows a model of static structural analysis for load applied at the center 8000N and the inflation pressure at inner side is 1.3bar.

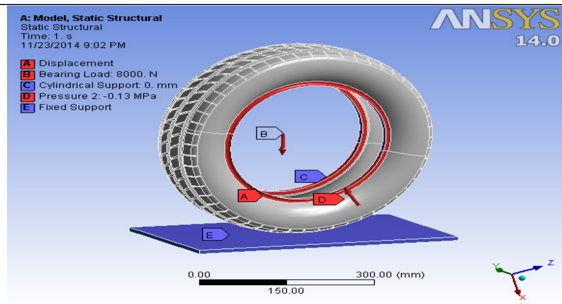


Fig.4 Static Loading

Figure shows the deflection of tire at load 8000N and the inflation pressure is 1.3bar

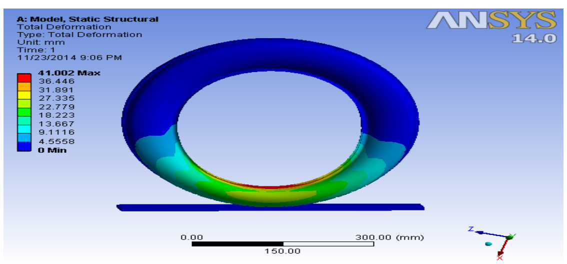


Fig.5 Total deformation

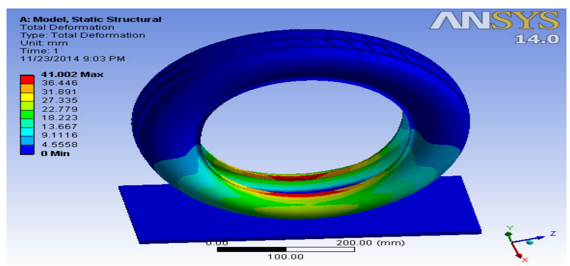


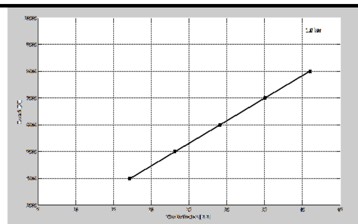
Fig.6 Total deformation

Table 5. Shows the total load deflection result obtain by simulation .it indicate an approximately linear relationship between load and deflection Result obtained from the finite element analysis

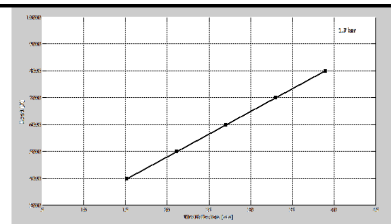
Table 5 Simulation load-deflection result

Load [N]	Tire Deflection [mm]				
	1.3 bar	1.7 bar	2 bar	2.4 bar	2.7 bar
4000	17.17	15.12	13.59	11.53	10
5000	23.13	21.08	19.55	17.5	15.96
6000	29.09	27.03	25.5	23.45	21.92
7000	35.05	33	31.46	29.41	27.88
8000	41.01	38.95	37.42	35.37	33.83

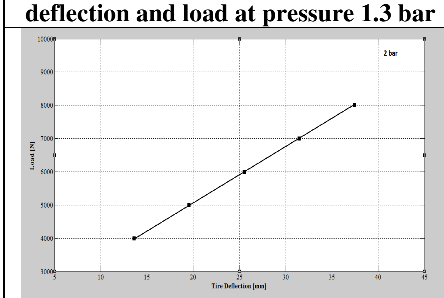
Graph shows the relationship between the deflection and load at the tire pressure 1.3, 1.7, 2, 2.4, 2.7bar.



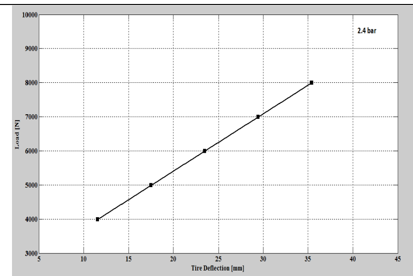
Graph.1 The relationship between the deflection and load at pressure 1.3 bar



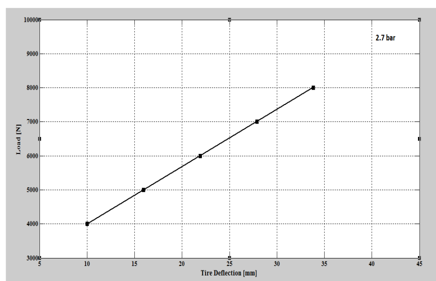
Graph.2 The relationship between the deflection and load at pressure 1.7 bar



Graph.3 The relationship between the deflection and load at pressure 2 bar



Graph.4 The relationship between the deflection and load at pressure 2.4bar



Graph.5 the relationship between the deflection and load at pressure 2.7 bar

CONCLUSION

A stationary passenger car tire P135170R12 vertically loaded against a horizontal surface was successfully investigated using three dimensional FE software. The Inflation pressure directly influences the stiffness of the tire. At constant inflation pressure load increases tire deflection increases. As inflation pressure increases, the stiffness of the tire also increases. Simulation result obtained using Ansys.14.0 software. The linear correlation is found between the deflection-load characteristics. Simulation result of the tire model will assess the optimum pressure in tire which is important for the safety of the vehicle and directly related to the deflection of the tire

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