

Experimental Investigation of Vertical Stiffness for Static Load of Different car Tyre using Air and Nitrogen

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Abstract Tyre stiffness plays a crucial role in vehicle ride comfort, durability and stability. Tyre stiffness depend on inflation pressure, tyre size, inflating fluid and loading condition. In this research work radial ply tyre size 165/70R13 and bias ply tyre size 165/80D13, check for it vertical stiffness by using Air and Nitrogen inflated tyre at different inflation pressure and gradually increasing static load. Measurement done on radial ply and bias ply tyre at different inflated pressure (25psi, 30psi, 35psi, 40psi) and different vertical static load (2000N, 3000N, 4000N, 5000N, 6000N) on tyre using air and nitrogen. Different method used for measuring vertical stiffness of tyre but load deflection method gave more reliable result as compare to other method. In this research work method was used is load deflection method for finding the vertical stiffness of the tyre.

Keywords- vertical stiffness, nitrogen, load deflection method, tubeless tyre property

I. INTRODUCTION

Tyre is subjected Tyre being a part which is subjected to a lot of fatigue load needs to be well designed. In last few decades, tyre manufacturers have done more research on different aspects of tyre performance parameters. The research work is being done both experimentally and theoretically by modeling tyre in different software^[1]. The basic requirement of tyre is its strength as strength is must criterion for the tyre to provide foundation to the vehicle having huge load. All the shocks mostly generated due to irregularity of road surfaces must be absorbed by tyre.

Stiffness of a tyre is crucial for a convenient ride for occupant likewise preventing the chassis and other working parts from being affected due to road roughness^[2]. Conventionally we use air for inflating tyres; the only option available is filling it with nitrogen but in both the cases there are some and the other drawback. Air has greater thermal coefficient of expansion as compared to nitrogen and thus when tyre heats up in summer season and at high speed due to friction, there are chances of tyre burst^[3]. In order to overcome this problem, people use nitrogen in case of high speed applications. But Nitrogen has its own drawbacks, Nitrogen refilling stations are not available everywhere and is costly. Atomic radii of nitrogen is greater than oxygen and thus pressure drop due to permeation in case of nitrogen filled tyres is less as compared to air filled tyres^[3]. Stiffness is measured static way by mounting wheel on standing position allows applying load and measured tyre deflection

$$C = \frac{W}{\delta} \left[\frac{N}{mm} \right] \dots \dots \dots [8]$$

1.1 Experimental Setup

Radial ply tyre (165/70R13) and bias ply tyre (165/80D13) are checked for its vertical stiffness using air and nitrogen inflated tyre. Load is apply using UTM machine and mild steel frame is support the tyre.

Experiment done on different inflation pressure (25 psi, 30 psi, 35psi, 40 psi) and different static load (2KN, 3KN, 4KN, 5KN, 6KN) to measured vertical stiffness of tyre.



Figure 1 experimental setup

name	parameter
1	Tyre frame
2	wheel rim
3	tyre
4	monitor screen

Table 1 UTM Specifications

Maximum load	1000 kN
Tensile Tests	Grip to grip distance : 50 to 1800mm Maximum elongation : 600mm Grips for rods : upto 65 mm dia Grips for flats : upto 65 mm
Compression Tests	Plate dia : upto 650 mm
Hardness tests	Length of Bending : 25 to 1150 mm Specimen

II METHODOLOGY

For finding stiffness of tyre load deflection method is used. Applying load and deflection is measured with help of UTM, which is display on monitor screen. When applied load is reach the 6000N, universal testing machine is automatically stop the process. Prepared the test setup and taking reading radial tyre stiffness is measured at different inflation pressure 25 psi, 30 psi, 35psi,40 psi and different static load 2000N, 3000N,4000N, 5000N, 6000N using inflating medium of air and nitrogen.

2.1 Result and analysis

Air filled radial ply tyre

Radial ply tyre (165/70R13) stiffness at different inflation pressure and different load using air filled tyre.

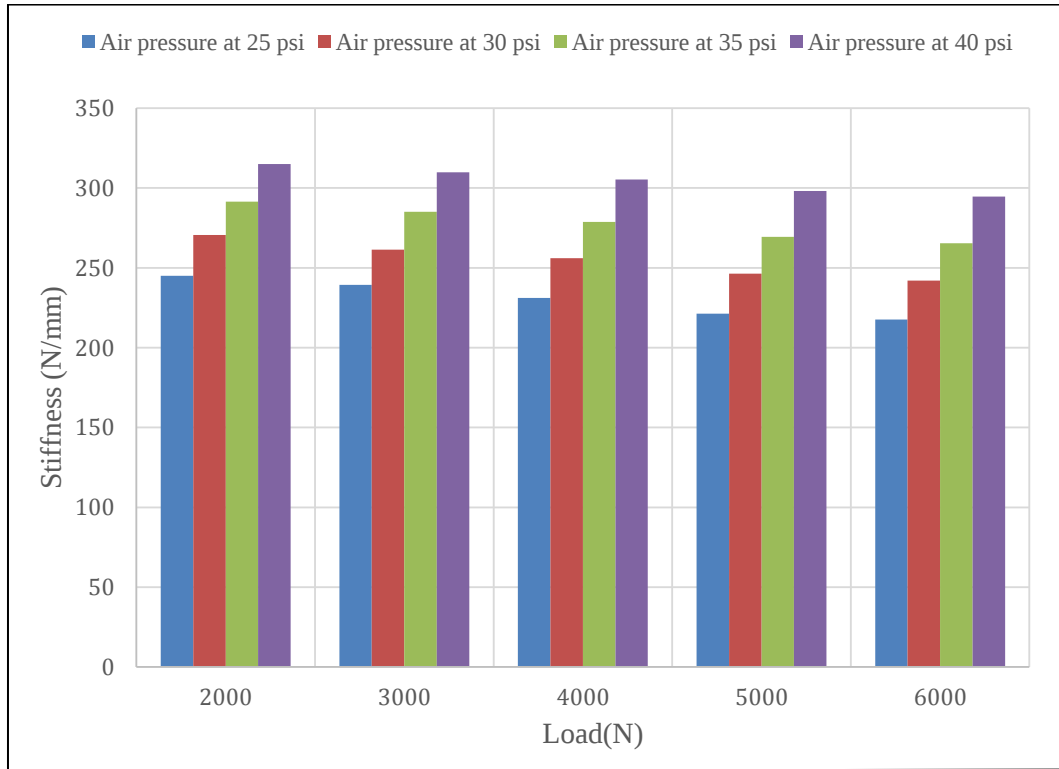


Figure 2 Stiffness vs Load

Figure 2 shows that as inflation pressure increase in the tyre stiffness of tyre is increase. When load increase on the tyre, stiffness of tyre is decrease. Stiffness of air filled radial tyre is increase 22.18 % as inflation pressure is increase from 25 psi pressure to 40 psi pressure at 2000 N constant load. Stiffness of air filled tyre is increase 245.09 N/mm at 25 psi pressure to 314.96 N/mm at 40 psi pressure. As load increase on the tyre, stiffness of tyre is decrease. Stiffness of air filled radial tyre is increase 22.78 % as inflation pressure increase from 25 psi pressure to 40 psi pressure at 3000 N constant load. Stiffness of air filled radial tyre is increase 24.32 % as inflation pressure increase from 25 psi pressure to 40 psi pressure at 4000 N constant load. Stiffness of air filled radial tyre is increase 25.76 % as inflation pressure increase from 25 psi pressure to 40 psi pressure at 5000 N constant load. Stiffness of air filled radial tyre is increase 26.12 % as inflation pressure increase from 25 psi pressure to 40 psi pressure at 6000 N constant load

Table 2

Air filled radial tyre								
Pressure at 25 psi			Pressure at 30 psi		Pressure at 35 psi		Pressure at 40 psi	
Load(N)	Deflection(mm)	Stiffness (N/mm)	Deflection(mm)	Stiffness (N/mm)	Deflection(mm)	Stiffness (N/mm)	Deflection(mm)	Stiffness (N/mm)
2000	8.16	245.098	7.39	270.635	6.86	291.545	6.35	314.960
3000	12.53	239.425	11.48	261.324	10.52	285.171	9.68	309.917
4000	17.31	231.080	15.62	256.081	14.35	278.745	13.1	305.343
5000	22.59	221.336	20.3	246.305	18.56	269.396	16.77	298.151
600	27.56	217.706	24.79	242.033	22.61	265.369	20.36	294.695

Nitrogen filled radial ply tyre

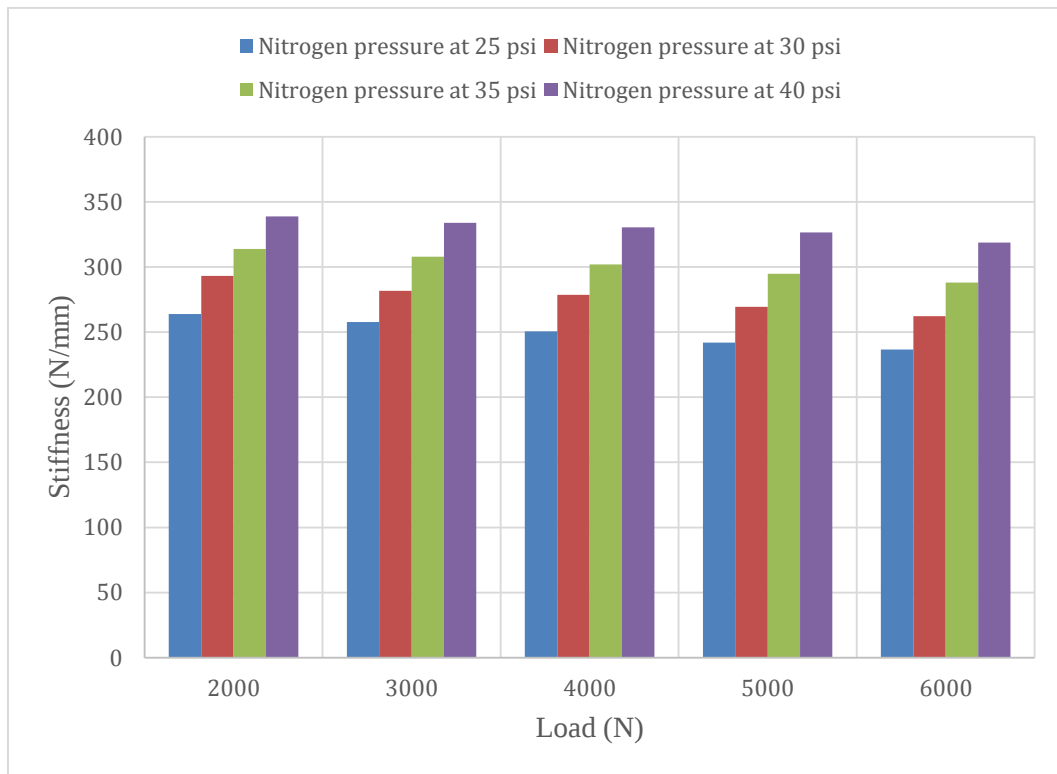


Figure 3 Stiffness vs Load

Figure 3 shows that nitrogen filled tyre stiffness is higher than air filled tyre. Deflection for nitrogen filled tyre is less as compare to air filled tyre. Stiffness of nitrogen filled radial tyre is increase 22.16 % as inflation pressure is increase from 25 psi pressure to 40 psi pressure at 2000 N constant load. Stiffness of nitrogen filled radial tyre is increase 22.85 % as inflation pressure is increase from 25 psi pressure to 40 psi pressure at 3000 N constant load. Stiffness of nitrogen filled tyre is varying minimum from 236.89 N/mm to maximum stiffness is 338.98 N/mm at different inflation pressure and different static load.

Table 3

Nitrogen filled radial tyre

Nitrogen filled radial tyre								
Pressure at 25 psi			Pressure at 30 psi		Pressure at 35 psi		Pressure at 40 psi	
Load(N)	Deflection(mm)	Stiffness (N/mm)	Deflection(mm)	Stiffness (N/mm)	Deflection(mm)	Stiffness (N/mm)	Deflection(mm)	Stiffness (N/mm)
2000	7.58	263.852	6.82	293.255	6.37	313.971	5.9	338.983
3000	11.64	257.731	10.65	281.690	9.74	308.008	8.98	334.075
4000	15.96	250.626	14.35	278.745	13.24	302.114	12.1	330.578
5000	20.67	241.896	18.56	269.396	16.96	294.811	15.31	326.583
600	25.36	236.593	22.87	262.352	20.83	288.046	18.82	318.809

Air filled bias ply tyre

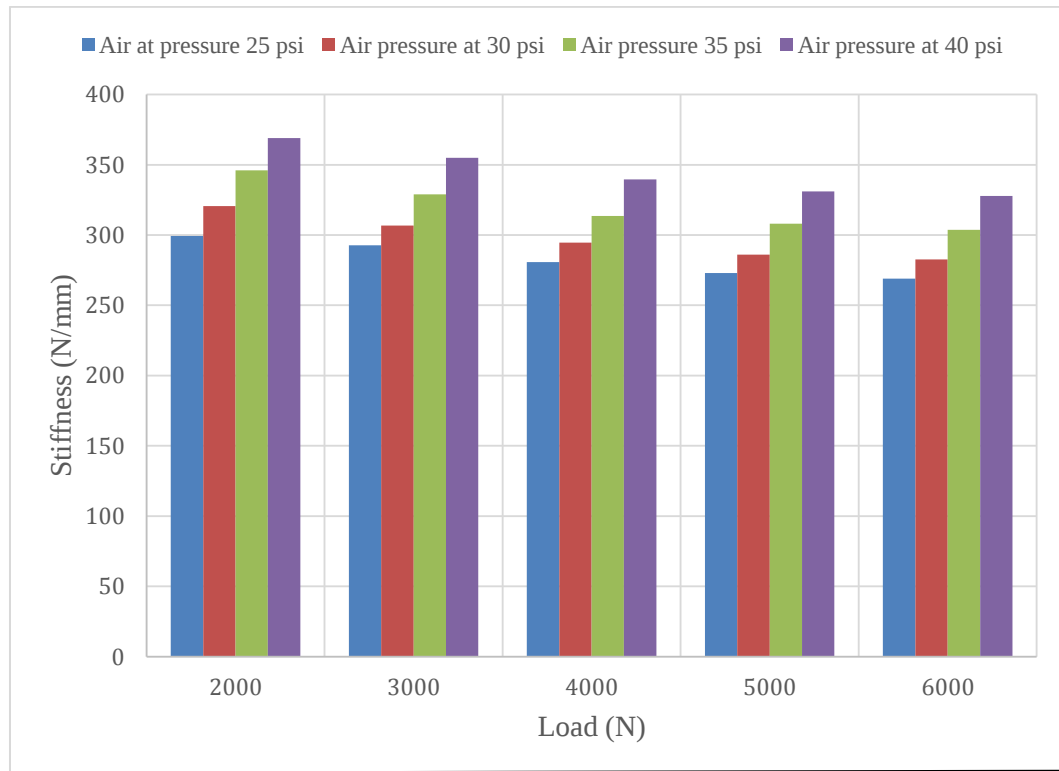


Figure 4 Stiffness vs Load

Figure 4 shows Stiffness of air filled bias tyre is increase 16.16 % as inflation pressure is increase from 25 psi pressure to 40 psi pressure at 2000 N constant load. Stiffness of air filled tyre is increase 299.40 N/mm at 25 psi pressure to 357.14 N/mm at 40 psi pressure. As load increase on the tyre stiffness of tyre is decrease. Stiffness of air filled bias tyre is increase 17.56 % as inflation pressure increase from 25 psi pressure to 40 psi pressure at 3000 N constant load. Stiffness of air filled bias tyre is increase 17.33 % as inflation pressure increase from 25 psi pressure to 40 psi pressure at 4000 N constant load. Stiffness of air filled bias tyre is increase 17.57 % as inflation pressure increase from 25 psi pressure to 40 psi pressure at 5000 N constant load. Stiffness of air filled bias tyre is increase 17.97 % as inflation pressure increase from 25 psi pressure to 40 psi pressure at 6000 N constant load.

Table 4
Air filled bias tyre

Air filled bias tyre								
Pressure at 25 psi			Pressure at 30 psi		Pressure at 35 psi		Pressure at 40 psi	
Load(N)	Deflection(mm)	Stiffness (N/mm)	Deflection(mm)	Stiffness (N/mm)	Deflection(mm)	Stiffness (N/mm)	Deflection(mm)	Stiffness (N/mm)
2000	6.68	299.401	6.24	320.512	5.78	346.020	5.42	362.31
3000	10.25	292.682	9.78	306.748	9.12	328.947	8.45	355.029
4000	14.25	280.701	13.58	294.550	12.76	313.479	11.78	339.558
5000	18.32	272.925	17.48	286.041	16.23	308.071	15.1	331.125
600	22.31	268.937	21.23	282.618	19.76	303.643	18.3	327.868

Nitrogen filled bias ply tyre

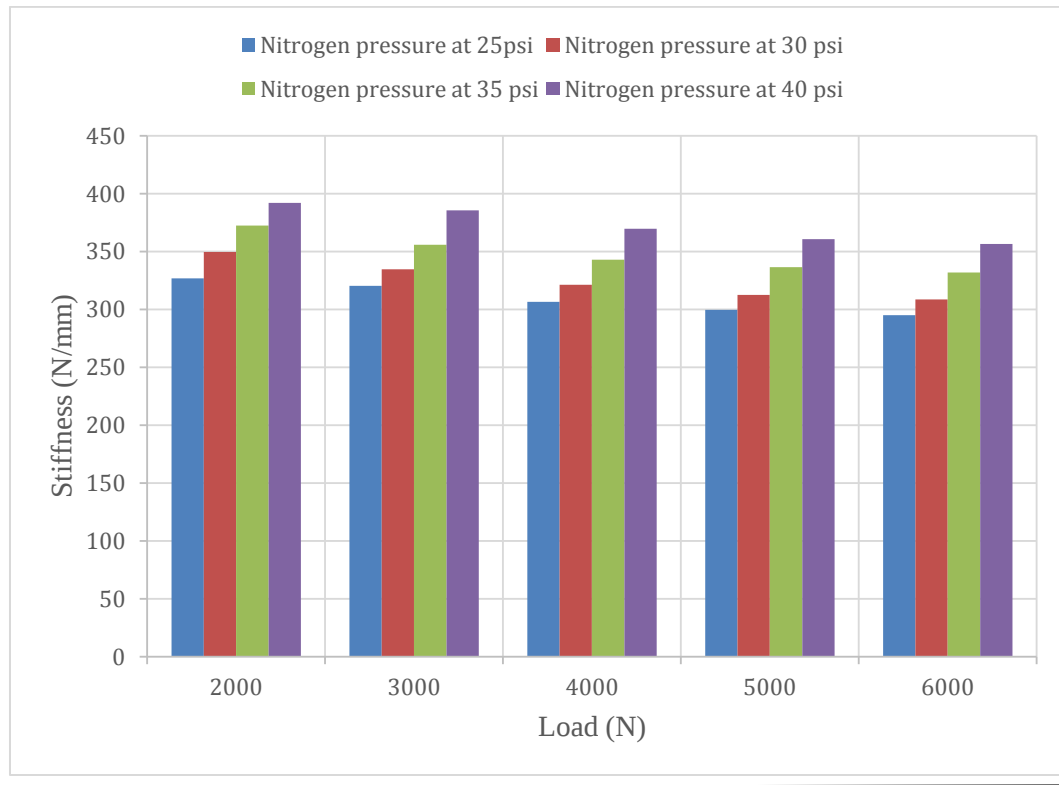


Figure 5 Stiffness vs Load

Figure 5 shows Stiffness of nitrogen filled bias tyre is increase 16.66 % as inflation pressure is increase from 25 psi pressure to 40 psi pressure at 2000 N constant load. Stiffness of nitrogen filled bias tyre is increase 16.88 % as inflation pressure is increase from 25 psi pressure to 40 psi pressure at 3000 N constant load. Stiffness of nitrogen filled tyre is varying minimum from 294.99 N/mm to maximum stiffness is 392.15 N/mm at different inflation pressure and different static load. Stiffness of nitrogen filled bias tyre is increase 17.08 % as inflation pressure is increase from 25 psi pressure to 40 psi pressure at 4000 N constant load. Stiffness is increase as inflation pressure is increase. Stiffness is increase as inflation pressure is increase. Stiffness of nitrogen filled bias tyre is increase 17 % as inflation pressure is increase from 25 psi pressure to 40 psi pressure at 5000 N constant load. Stiffness of nitrogen filled bias tyre is increase 17.28 % as inflation pressure is increase from 25 psi pressure to 40 psi pressure at 6000 N constant load.

Table 5
 Nitrogen filled bias tyre

Nitrogen filled bias tyre								
Pressure at 25 psi			Pressure at 30 psi		Pressure at 35 psi		Pressure at 40 psi	
Load(N)	Deflection(mm)	Stiffness (N/mm)	Deflection(mm)	Stiffness (N/mm)	Deflection(mm)	Stiffness (N/mm)	Deflection(mm)	Stiffness (N/mm)
2000	6.12	326.797	5.72	349.650	5.37	372.439	5.1	392.15
3000	9.36	320.512	8.96	334.821	8.43	355.871	7.78	385.604
4000	13.05	306.513	12.45	321.285	11.66	343.053	10.82	369.685
5000	16.69	299.580	16	312.5	14.86	336.473	13.86	360.750
6000	20.34	294.985	19.44	308.641	18.07	332.042	16.83	356.506

III. CONCLUSION

- 1) Radial tyre stiffness is measured different static load and different inflation pressure using air and nitrogen. Nitrogen filled tyre give 7 to 8.5 % higher stiffness as compare to the air filled tyre at inflation pressure 25 psi to 40 psi and load 2000N to 6000N respectively. Stiffness of air filled tyre varying from 217 N/mm to 315 N/mm, and stiffness of nitrogen filled tyre is varying from 236 N/mm to 338 N/mm at inflation pressure 25 psi to 40 psi and load 2000N to 6000N load respectively.
- 2) Nitrogen filled bias tyre stiffness is 7 to 8.5% higher than air filled tyre at inflation pressure 25 psi to 40 psi and load 2000N to 6000N respectively. Air filled bias tyre stiffness is varying form 268.93 N/mm to 362.31 N/mm at inflation pressure 25 psi to 40 psi and static load 2000N to 6000N. Nitrogen filled bias tyre stiffness is varying from 294.9 N/mm to 392.15 N/mm. stiffness at inflation pressure 25 psi to 40 psi and static load 2000N to 6000N.
- 3) Tyre stiffness is highly affected by inflation pressure of tyre. Highest stiffness of tyre is given by 40 psi pressure. Air permeability is higher than nitrogen so that nitrogen filled tyre stiffness is higher than air filled tyre
- 4) Air filled bias tyre stiffness is 11 to 18 % higher stiffness as compare to air filled radial tyre at inflation pressure 25 psi to 40 psi and load 2000N to 6000N respectively.

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