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Stiffness Analysis of Two Wheeler Tyre Using Air, Nitrogen and Argon as Inflating Fluids

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ABSTRACT

Vertical radial stiffness for Ceat 90/100R10 tyre was measured using three different inflation fluids Air, Nitrogen and Argon. Tyre stiffness plays an important role in vehicle ride comfort, stability and damping of vibrations. The stiffness was measured using Load-Deflection method for different inflation pressures, inflation fluid and gradually increasing load in static condition. The stiffness was analyzed at inflation pressure [24, 26, 28, 30, 32, 34 psi] and load range [20, 40, 60, 80, 100, 120, 130, 140, 150 kg] for different inflation fluid filled in the tyre.

Keywords: Inflating fluid, Inflation pressure, Nitrogen, Tyre, Tyre vertical stiffness, Tyre radial stiffness, Tyre properties

I. INTRODUCTION

Tyre being a part which is subjected to a lot of fatigue needs to be well designed. In last few decades, tyre manufacturers have done a lot of research on different aspects of tyre performance parameters. The research work is being done both experimentally and theoretically by modelling tyre in different softwares. Many tyre models are being prepared so as to study effect of variation of different parameters on tyre performance. Few examples of such models are PAC 2002 Model, Pac-time tire model, ’89 and ’94 Pacejka Tire Models, 521-Tire Model, UA-Gim-Tire Model, FTire Model and many more. These tyre models help in analyzing them on different software such as Adams.

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. 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.

It has been found that for same pressure and load, stiffness of tyre varies as we vary the gas inside the tyre. Tyre deflection for fluid Nitrogen is less compare to Air for all pressures in case of Tata Nano tyre having size P135/70R12 [1]. Thus variation in inflating gas composition varies stiffness of tyre. As stiffness plays a vital role in vibration control, ride comfort, rolling resistance, fuel consumption and many other parameters, it is necessary to study this behavior for different gases. There is pressure loss in tyres due to permeation [4]. Nitrogen filled tyres show less pressure drop as compared to air filled tyres. This is due to the fact that nitrogen molecules have greater atomic radius as compared to oxygen molecules which form 21% of air constituent. This pressure drop ultimately results in drop in fuel efficiency, ride comfort tyre wear, and thus need to be monitored constantly. The variation in tyre pressure results in variation of rolling resistance and hence the fuel consumption. Generally, as we increase the tyre pressure the rolling resistance decreases and thus the fuel consumption also decreases [5]. Inflation pressure, rolling speed, tyre size and tyre age were found to be important factors affecting the tyre stiffness [2]. CFD analysis showed that tyre lost air pressure irrespective of inflating medium [3].

Experimental Setup:

A two wheeler tyre Ceat 90/100R10 was selected for the study of stiffness analysis. A rig was manufactured for the stiffness testing of the tyre using air as inflation fluid. The rig consisted of a mild steel plate which acted as a rigid base. It supported four vertical mild steel bars which guided the vertical linear

motion of the loading platform. This was achieved by using four linear bearings. The tyre was fitted below the loading platform using two rigid mild steel bars. These bars were directly welded to the platform in order to eliminate damping.

Figure 1. Tyre test rig.

Figure 2. Tyre test rig with loading.

The tip of the digital vernier height gauge was touched above the axle of the tyre at zero load condition. Further, a load of 20 kg was applied which led to deflection of tyre, hence the axle shifted downwards. Then the tip of vernier height gauge was again touched above the axle. The difference in the readings obtained in the zero load and the loaded condition gave the deflection of the tyre. Then, a further load of 20 kg i.e. a total of 40kg, was applied and further deflections were noted. This was repeated for loadings upto 150kg.

This complete procedure was repeated for inflating fluids nitrogen and argon.

II. RESULTS

Results are tabulated in two forms.

1. Comparison of stiffness values of tyre filled with one fluid at different pressures. (Table no. 1,2,3)
2. Comparison of stiffness values of tyre filled with three different fluids at same pressure. (Table no. 4-11)

Table 1. Readings for air at different load and pressure:

Pressure (psi)	Force (N)	Deflection (mm)	Stiffness (N/mm)	Average stiffness (N/mm)	Pressure (psi)	Force (N)	Deflection (mm)	Stiffness (N/mm)	Average stiffness (N/mm)
34	196.2	1.76	111.477	**131.286**	28	196.2	1.74	112.759	**126.009**
	392.4	3.31	118.55			392.4	3.39	115.752	
	588.6	4.76	123.655			588.6	4.91	119.878	
	784.8	5.87	133.697			784.8	6.42	122.243	
	981	7.22	135.873			981	7.68	127.734	
	1177.2	8.5	138.494			1177.2	8.86	132.867	
	1275.3	9.15	139.377			1275.3	9.58	133.121	
	1373.4	9.77	140.573			1373.4	10.28	133.599	
	1471.5	10.52	139.876			1471.5	10.81	136.124	
32	196.2	1.74	112.759	**125.819**	26	196.2	1.78	110.225	**120.201**
	392.4	3.61	108.698			392.4	3.49	112.436	
	588.6	5.02	117.251			588.6	5.19	113.41	
	784.8	6.15	127.61			784.8	6.74	116.439	
	981	7.44	131.855			981	8.14	120.516	
	1177.2	8.88	132.568			1177.2	9.37	125.635	
	1275.3	9.6	132.844			1275.3	10.04	127.022	
	1373.4	10.2	134.647			1373.4	10.82	126.932	
	1471.5	10.97	134.139			1471.5	11.39	129.192	
30	196.2	1.71	114.737	**122.242**	24	196.2	1.98	99.0909	**105.428**
	392.4	3.44	114.07			392.4	4.1	95.7073	
	588.6	4.96	118.669			588.6	5.15	114.291	
	784.8	6.25	125.568			784.8	7.49	104.78	
	981	7.79	125.931			981	9.33	105.145	
	1177.2	9.29	126.717			1177.2	11.03	106.727	
	1275.3	10.36	123.098			1275.3	11.86	107.53	
	1373.4	10.98	125.082			1373.4	12.78	107.465	
	1471.5	11.65	126.309			1471.5	13.61	108.119	

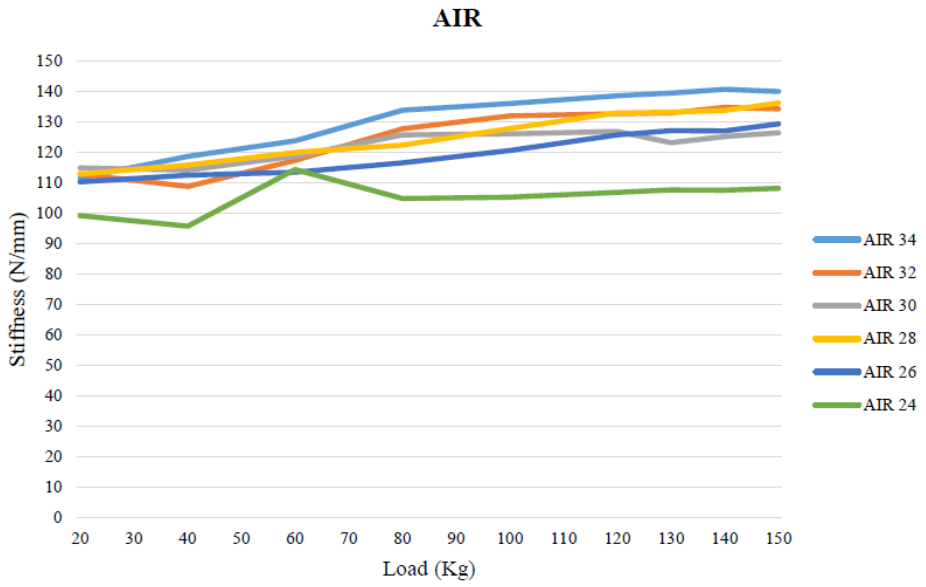

Figure 3. Stiffness vs load for air at different pressure

Table 2. Readings for nitrogen at different load and pressure:

Pressure (psi)	Force (N)	Deflection (mm)	Stiffness (N/mm)	Average stiffness (N/mm)	Pressure (psi)	Force (N)	Deflection (mm)	Stiffness (N/mm)	Average stiffness
34	196.2	1.58	124.177	**124.495**	28	196.2	1.87	104.92	**108.64**
	392.4	3.44	114.07			392.4	3.89	100.874	
	588.6	5.08	115.866			588.6	5.55	106.054	
	784.8	6.35	123.591			784.8	7.26	108.099	
	981	7.77	126.255			981	9	109	
	1177.2	9.2	127.957			1177.2	10.68	110.225	
	1275.3	9.78	130.399			1275.3	11.57	110.225	
	1373.4	10.47	131.175			1373.4	12.13	113.223	

	1471.5	11.59	126.963			1471.5	12.78	115.141	
32	196.2	1.6	122.625	**118.354**	26	196.2	1.92	102.188	**105.3**
	392.4	3.5	112.114			392.4	3.96	99.0909	
	588.6	5.13	114.737			588.6	5.8	101.483	
	784.8	6.48	121.111			784.8	7.74	101.395	
	981	8	122.625			981	9.35	104.92	
	1177.2	10.17	115.752			1177.2	11.13	105.768	
	1275.3	10.81	117.974			1275.3	11.77	108.352	
	1373.4	11.56	118.806			1373.4	12.31	111.568	
	1471.5	12.32	119.44			1471.5	13.03	112.932	
30	196.2	1.62	121.111	**117.498**	24	196.2	2.2	89.1818	**104.652**
	392.4	3.54	110.847			392.4	3.94	99.5939	
	588.6	5.19	113.41			588.6	5.9	99.7627	
	784.8	6.61	118.729			784.8	7.4	106.054	
	981	8.27	118.622			981	9.08	108.04	
	1177.2	9.82	119.878			1177.2	10.76	109.405	
	1275.3	10.76	118.522			1275.3	11.72	108.814	
	1373.4	11.66	117.787			1373.4	12.48	110.048	
	1471.5	12.41	118.574			1471.5	13.26	110.973	

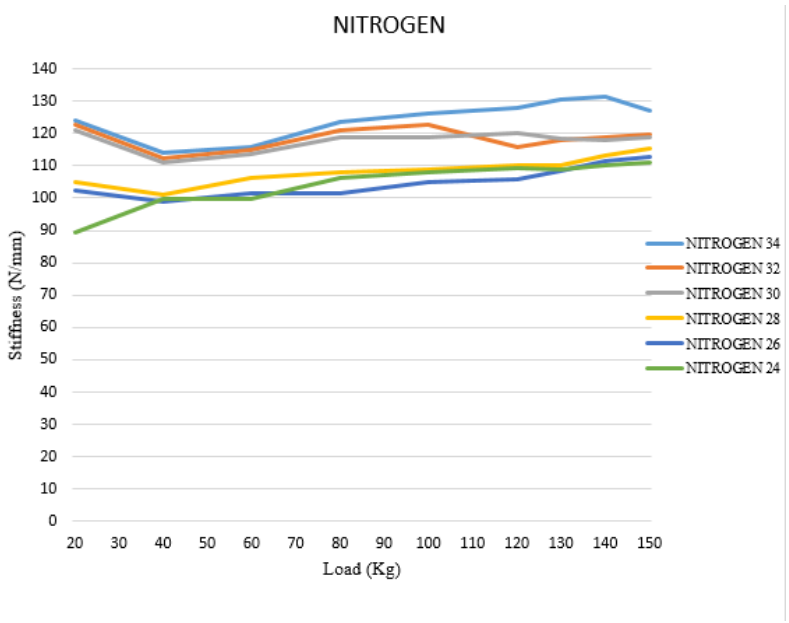

Figure 4. Stiffness vs load for nitrogen at different pressure

Table 3. Readings for argon at different load and pressure:

Pressure (psi)	**Force (N)**	**Deflection (mm)**	**Stiffness (N/mm)**	**Average stiffness (N/mm)**	**Pressure (psi)**	**Force (N)**	**Deflection (mm)**	**Stiffness (N/mm)**	**Average stiffness**
34	196.2	1.84	106.6304	**106.25**	28	196.2	2.23	87.98206	**103.499**
	392.4	4.03	97.36973			392.4	4.35	90.2069	
	588.6	5.88	100.102			588.6	6.11	96.33388	
	784.8	7.64	102.7225			784.8	7.57	103.6724	
	981	9.22	106.3991			981	9.24	106.1688	
	1177.2	10.87	108.2981			1177.2	10.56	111.4773	
	1275.3	11.53	110.6071			1275.3	11.42	111.6725	
	1373.4	12.33	111.3869			1373.4	12.32	111.4773	
	1471.5	13.05	112.7586			1471.5	13.08	112.5	
32	196.2	1.63	120.3681	**116.31**	26	196.2	1.68	116.7857	**113.575**
	392.4	3.72	105.4839			392.4	3.62	108.3978	
	588.6	5.41	108.7985			588.6	5.33	110.4315	
	784.8	6.97	112.5968			784.8	7.27	107.9505	
	981	8.44	116.2322			981	8.67	113.1488	
	1177.2	9.94	118.4306			1177.2	10.25	114.8488	
	1275.3	10.6	120.3113			1275.3	11.08	115.0993	
	1373.4	11.3	121.5398			1373.4	11.65	117.8884	
	1471.5	11.96	123.0351			1471.5	12.51	117.6259	
30	196.2	1.68	116.7857	**110.612**	24	196.2	2.36	83.13559	**95.596**
	392.4	3.82	102.7225			392.4	4.71	83.3121	

	588.6	5.66	103.9929			588.6	6.43	91.53966	
	784.8	7.24	108.3978			784.8	8.21	95.59074	
	981	9.13	107.448			981	10	98.1	
	1177.2	10.42	112.975			1177.2	11.78	99.93209	
	1275.3	11.45	111.3799			1275.3	12.45	102.4337	
	1373.4	11.94	115.0251			1373.4	13.28	103.4187	
	1471.5	12.6	116.7857			1471.5	14.3	102.9021	

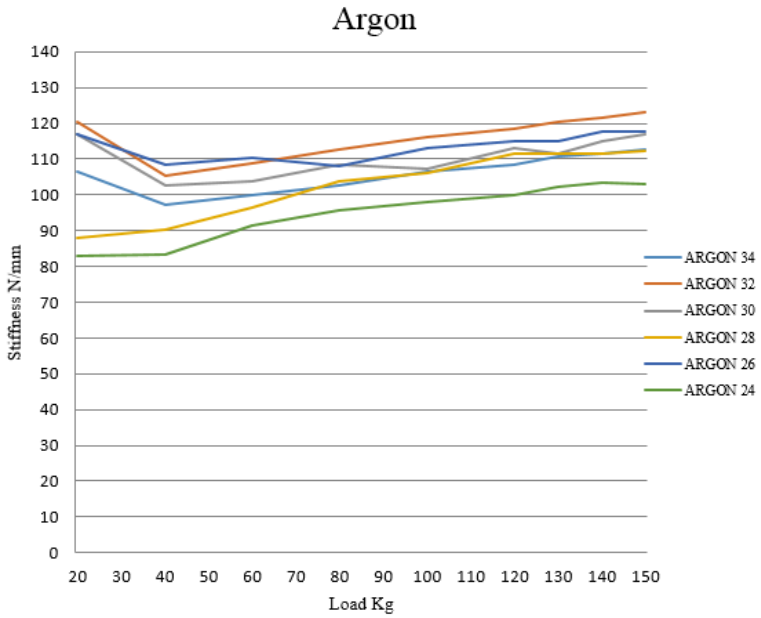

Figure 5. Stiffness vs load for argon at different pressure.

Table 4. Comparison of stiffness values for different gases at pressure 34 psi

Pressure (psi)	Weight (kg)	Force (N)	AIR		NITROGEN		ARGON	
			Deflection (mm)	Stiffness (N/mm)	Deflection (mm)	Stiffness (N/mm)	Deflection (mm)	Stiffness (N/mm)
34	20	196.2	1.86	105.4839	1.58	124.1772	1.84	106.6304
	40	392.4	3.31	118.5498	3.44	114.0698	4.03	97.36973
	60	588.6	4.76	123.6555	5.08	115.8661	5.88	100.102
	80	784.8	5.87	133.6968	6.35	123.5906	7.64	102.7225
	100	981	7.22	135.8726	7.77	126.2548	9.22	106.3991
	120	1177.2	8.5	138.4941	9.2	127.9565	10.87	108.2981
	130	1275.3	9.15	139.377	9.78	130.3988	11.53	110.6071
	140	1373.4	9.77	140.5732	10.47	131.1748	12.33	111.3869
	150	1471.5	10.52	139.8764	11.59	126.9629	13.05	112.7586

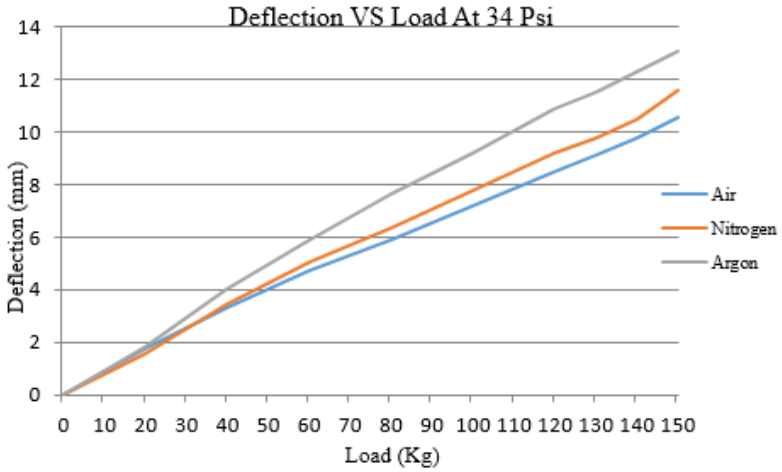

Figure 6. Comparison of deflection vs load at 34 psi

Table 5. Comparison of stiffness values for different gases at pressure 32 psi

Pressure (psi)	Weight (kg)	Force (N)	AIR		NITROGEN		ARGON	
			Deflection (mm)	Stiffness (N/mm)	Deflection (mm)	Stiffness (N/mm)	Deflection (mm)	Stiffness (N/mm)
32	20	196.2	1.74	112.7586	1.6	122.625	1.63	120.3681
	40	392.4	3.61	108.6981	3.5	112.1143	3.72	105.4839
	60	588.6	5.02	117.251	5.13	114.7368	5.41	108.7985
	80	784.8	6.15	127.6098	6.48	121.1111	6.97	112.5968
	100	981	7.44	131.8548	8	122.625	8.44	116.2322
	120	1177.2	8.88	132.5676	10.17	115.7522	9.94	118.4306
	130	1275.3	9.6	132.8438	10.81	117.9741	10.6	120.3113
	140	1373.4	10.2	134.6471	11.56	118.8062	11.3	121.5398
	150	1471.5	10.97	134.1386	12.32	119.4399	11.96	123.0351

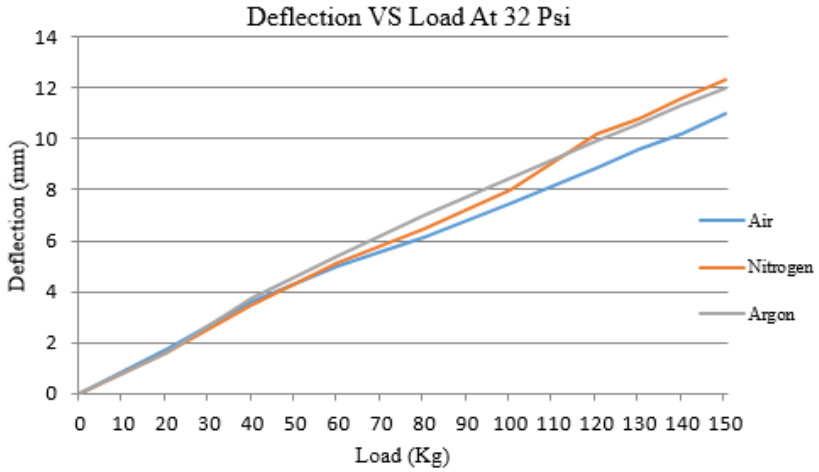

Figure 7. Comparison of deflection vs load at 32 psi

Table 6. Comparison of stiffness values for different gases at pressure 30 psi

Pressure (psi)	Weight (kg)	Force (N)	AIR		NITROGEN		ARGON	
			Deflection (mm)	Stiffness (N/mm)	Deflection (mm)	Stiffness (N/mm)	Deflection (mm)	Stiffness (N/mm)
30	20	196.2	1.71	114.7368	1.62	121.1111	1.68	116.7857
	40	392.4	3.44	114.0698	3.54	110.8475	3.82	102.7225
	60	588.6	4.96	118.6694	5.19	113.4104	5.66	103.9929
	80	784.8	6.25	125.568	6.61	118.7292	7.24	108.3978
	100	981	7.79	125.9307	8.27	118.6215	9.13	107.448
	120	1177.2	9.29	126.7169	9.82	119.8778	10.42	112.975
	130	1275.3	10.36	123.0985	10.76	118.5223	11.45	111.3799
	140	1373.4	10.98	125.082	11.66	117.7873	11.94	115.0251
	150	1471.5	11.65	126.309	12.41	118.5737	12.6	116.7857

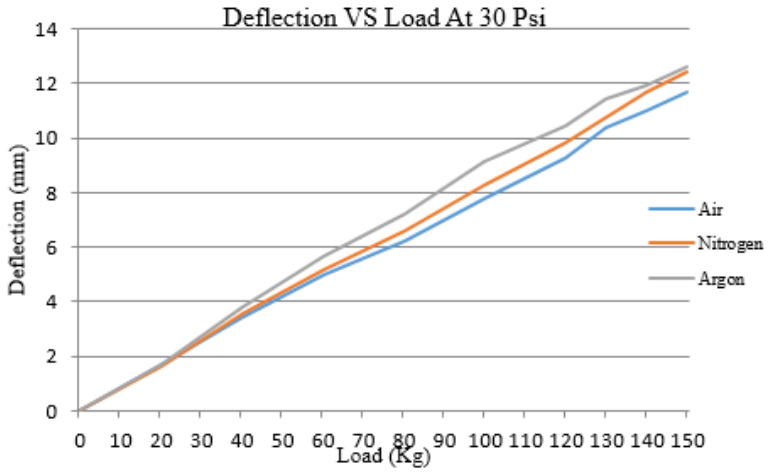

Figure 8. Comparison of deflection vs load at 30 psi

Table 7. Comparison of stiffness values for different gases at pressure 28 psi

Pressure (psi)	Weight (kg)	Force (N)	AIR		NITROGEN		ARGON	
			Deflection (mm)	Stiffness (N/mm)	Deflection (mm)	Stiffness (N/mm)	Deflection (mm)	Stiffness (N/mm)
28	20	196.2	1.74	112.7586	1.87	104.9198	2.23	87.98206
	40	392.4	3.39	115.7522	3.89	100.874	4.35	90.2069
	60	588.6	4.91	119.8778	5.55	106.0541	6.11	96.33388
	80	784.8	6.42	122.243	7.26	108.0992	7.57	103.6724
	100	981	7.68	127.7344	9	109	9.24	106.1688
	120	1177.2	8.86	132.8668	10.68	110.2247	10.56	111.4773
	130	1275.3	9.58	133.1211	11.57	110.2247	11.42	111.6725
	140	1373.4	10.28	133.5992	12.13	113.2234	12.32	111.4773
	150	1471.5	10.81	136.124	12.78	115.1408	13.08	112.5

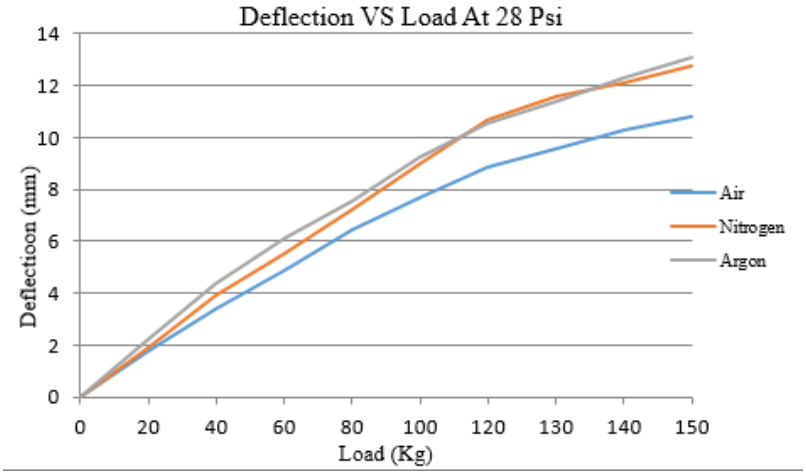

Figure 9. Comparison of deflection vs load at 28 psi

Table 8. Comparison of stiffness values for different gases at pressure 26 psi

Pressure (psi)	Weight (kg)	Force (N)	AIR		NITROGEN		ARGON	
			Deflection (mm)	Stiffness (N/mm)	Deflection (mm)	Stiffness (N/mm)	Deflection (mm)	Stiffness (N/mm)
26	20	196.2	1.78	110.2247	1.92	102.1875	1.68	116.7857
	40	392.4	3.49	112.4355	3.96	99.09091	3.62	108.3978
	60	588.6	5.19	113.4104	5.8	101.4828	5.33	110.4315
	80	784.8	6.74	116.4392	7.74	101.3953	7.27	107.9505
	100	981	8.14	120.516	9.35	104.9198	8.67	113.1488
	120	1177.2	9.37	125.635	11.13	105.7682	10.25	114.8488
	130	1275.3	10.04	127.0219	11.77	108.3517	11.08	115.0993
	140	1373.4	10.82	126.9316	12.31	111.5678	11.65	117.8884
	150	1471.5	11.39	129.1923	13.03	112.9317	12.51	117.6259

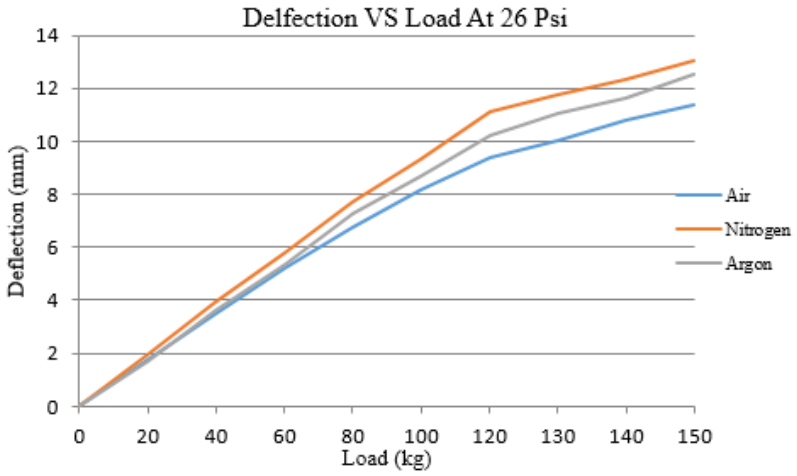

Figure 10. Comparison of deflection vs load at 26 psi

Table 9. Comparison of stiffness values for different gases at pressure 24 psi

Pressure (psi)	Weight (kg)	Force (N)	AIR		NITROGEN		ARGON	
			Deflection (mm)	Stiffness (N/mm)	Deflection (mm)	Stiffness (N/mm)	Deflection (mm)	Stiffness (N/mm)
24	20	196.2	1.98	99.09091	2.2	89.18182	2.36	83.13559
	40	392.4	4.1	95.70732	3.94	99.59391	4.71	83.3121
	60	588.6	5.15	114.2913	5.9	99.76271	6.43	91.53966
	80	784.8	7.49	104.7797	7.4	106.0541	8.21	95.59074
	100	981	9.33	105.1447	9.08	108.0396	10	98.1
	120	1177.2	11.03	106.7271	10.76	109.4052	11.78	99.93209
	130	1275.3	11.86	107.5295	11.72	108.814	12.45	102.4337
	140	1373.4	12.78	107.4648	12.48	110.0481	13.28	103.4187
	150	1471.5	13.61	108.119	13.26	110.9729	14.3	102.9021

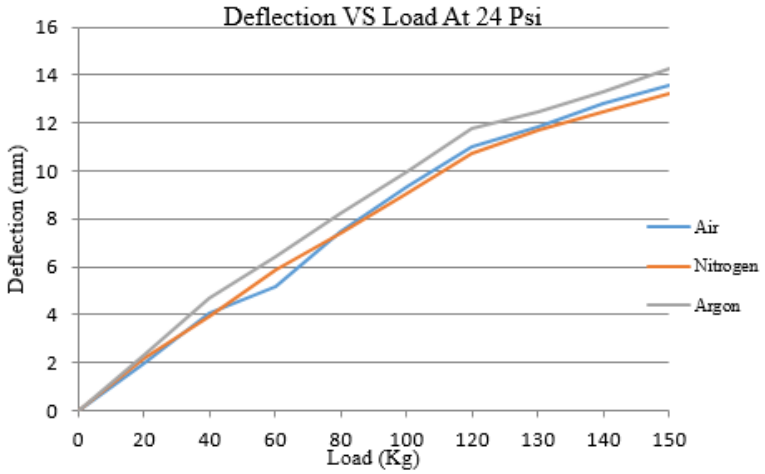

Figure 11. Comparison of deflection vs load at 24 psi

III. CONCLUSION

1. Vertical Radial stiffness of Ceat 90/100R10 tyre is investigated using load deflection method when the tyre is under static load condition.
2. Deflection in tyre is greater for fluid Nitrogen as compared to Air for all pressures and for Argon is maximum.
3. As the inflation pressure increases, the stiffness of the tire also increases in all three cases.
4. Stiffness of tyre filled with Air is found to be maximum followed by the stiffness of Nitrogen and then Argon filled tyre.

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