

Comparative Performance of Different Types of Pneumatic Tyres Used in Camel Carts under Sandy Terrain Condition

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Abstract: Considerable amount of energy is lost due to use of improper tyre design and other related parameters. Four animal drawn vehicle (ADV) tyres of 5.00-19, 6.00-19, 7.00-19, and 8.00-19 size and two types of automobile discarded tyres of size 9.00-20 were selected to test their performance under controlled soil bin conditions in sand. These tyres were tested at five normal loads of 200, 400, 600, 800 and 1000 daN in the draught capacity of camels. Inflation pressure varied from 172.5 to 379.5 kPa for the ADV tyres and 69 to 345 kPa for automobile discarded tyres. A tyre test carriage was used to mount the test wheels of different sizes. Performance of the wheels was evaluated on the basis of towing force at forward speed of 3.1 km h⁻¹. The performance of the automobile discarded tyres was found superior to that of ADV tyres on the basis of reduced rolling resistance.

Key words: Camel cart, tyre, ADV, inflation pressure, normal load and rolling resistance.

The use of mechanized transportation systems is difficult in the rural areas due to poor network of roads. Further, the mechanized mode of transportation system is beyond the reach of small and marginal farmers due to its high initial investment and operational cost owing to steep rise in the cost of petroleum products. The animal drawn transportation system is, therefore still dominating transport in rural areas.

The carts are extensively used for transport of human beings, farm produce, water, building material, etc. The camel carts are generally fitted with pneumatic wheels because the performance of the free rolling rigid wheels is much inferior to that of the same size of pneumatic tyres of low inflation pressure especially in loose dry sand under high vertical loads. The

use of pneumatic wheel results in the decrease of draught due to low rolling resistance (McAllister *et al.*, 1979; Wang and Reece, 1984). The shock absorbed by the pneumatic wheels also provides comfort to riders and to draught animals. The automobile discarded tyres (unbuffed and buffed) as well as the tyres designed especially for animal drawn vehicles (ADV) of various sizes are fitted in the camel carts (Singh and Verma, 1987; Anonymous, 2000, 2002). The automobile discarded tyres that are directly used in camel carts without any modification are designated as unbuffed tyres and the tyres with tread portion removed are designated as buffed tyres.

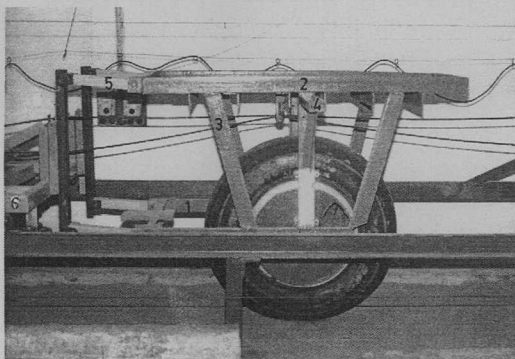
Due to variation in cart design, wheel size, wheel type and track conditions the payload capacity of camel carts varies from

1.2 to 2.0 t. The large variations in the size and shape of the wheels lead to improper utilization of camel power.

The tyre design parameters such as diameter, section width, section height, inflation pressure, carcass construction and load deflection relationship and system parameters such as normal load, speed and terrain characteristics play a vital role in performance of pneumatic towed wheels. Keeping above in view, the present study was undertaken to compare the performance of different types of pneumatic tyres used in camel carts under controlled soil bin conditions.

Materials and Methods

A tyre test carriage, consisting of wheel axle mounting frame, loading platform, lifting arms, parallel bar linkage system and axle assembly, was used to mount the single wheel of different sizes (Fig. 1). A four bar parallel linkage system provided free vertical movement to test carriage and helped in transferring the load



1. Axle mounting frame 2. Loading platform
3. Side supports 4. Lifting arm 5. Parallel bar linkage 6. Pull arm

Fig. 1. Tyre test carriage.

of the test carriage solely on the wheel. Tyre test carriage was towed with the help of wire rope powered by linear motion transmission system. The ranges of various parameters were selected taking into consideration the normal values observed in the field except the inflation pressure, which reflects the maximum and minimum range as recommended by the manufacturer.

The test tyres comprised of four ADV tyres of sizes 5.00-19 (T_1), 6.00-19 (T_2), 7.00-19 (T_3), and 8.00-19 (T_4) and two types of automobile discarded tyres (unbuffed and buffed) of size 9.00-20 (T_5 and T_6). The specifications of the test tyres are given in Table 1. Based on the deflection characteristics (Tiwari *et al.*, 2004) tyres T_1 and T_2 were tested at 200, 400 and 600 daN loads while the tyres T_3 and T_4 were tested at five normal loads (200, 400, 600, 800 and 1000 daN). Each load was tested at four levels of inflation pressure (172.5, 241.5, 310.5 and 379.5 kPa) and soil compaction level of 3.4 MPa m^{-1} . Automobile discarded tyres were tested at five normal loads (200-1000 daN) and in the inflation pressure range of 69-345 kPa. Soil compaction level was kept same as maintained for ADV tyres.

Soil bin filled with dry sand was used to test the performance of tyres (rolling resistance) under controlled conditions. Before filling the soil bin with sand of proper size, few sand samples were collected from desert areas where camel carts are in use. A soil processing trolley consisted of a rotary tiller; a leveler blade and compaction roller was used to prepare test track in the soil bin.

Before each test, the soil bed was processed using the soil processing trolley.

A hand operated standard soil cone penetrometer was used to measure the cone index of the soil at five different places in the depth range of 0-150 mm. The soil processing was repeated if variation in compaction was large. Towing trolley, attached with tyre test carriage, was coupled with soil processing trolley through ring transducer to record the towing force, i.e. rolling resistance. Replicated tests were conducted at a forward speed of 3.1 km h⁻¹ to cover a length of 5.5 m in the soil bin and rolling resistance was recorded using a two channel dynograph recorder.

Results and Discussion

Performance of ADV tyres

The data indicate that the rolling resistance increased with the increasing load at all inflation pressures for all tyres (Table 2). The results confirm the findings of McAllister *et al.* (1979). Less rolling resistance at low normal loads can be attributed to sufficient soil strength to support the wheel with insignificant sinkage. The wheels have neither to overcome the resistance offered by the surface in compacting it nor shearing it. The force due to adhesion is the only factor, and

hence the rolling resistance is reduced to a large extent.

In general, the rolling resistance of all the tyres increased with inflation pressure at all the normal loads (Table 2). The rolling resistance was minimum at an inflation pressure of 172.5 kPa and it increased rapidly with increase in inflation pressure up to 310.5 kPa. Beyond 310.5 kPa there was no change in rolling resistance. Janosi (1961), McAllister (1983), Wang *et al.* (1984) and Verma and Singh (1994) observed similar trends for rolling resistance. The increase in rolling resistance may be due to increase in tyre stiffness with inflation pressure, which resulted in less deformation in tyre and it works as a rigid wheel beyond a certain inflation pressure. The resistance in such a case depends only on load.

Out of four ADV tyres tested the tyre T₁ had the maximum rolling resistance at all loads and inflation pressures. This may be attributed to its narrow area of supporting contact surface due to which the tyre failed to hold enough volume of soil under compression resulting in increased sinkage and thereby rolling resistance. The tyre T₄ indicated minimum rolling resistance in range of 17-70 daN at lower normal loads

Table 1. Specifications of experimental tyres

Tyre type	Tyre code	Tyre size	Diameter (D), mm	Section width (b), mm	Section height (h), mm	b/D
ADV tyres	T1	5.00-19	745	130	115	0.174
	T2	6.00-19	790	160	125	0.202
	T3	7.00-19	850	200	160	0.235
	T4	8.00-19	890	220	190	0.247
Automobile discarded tyres	T5	9.00-20	975	270	210	0.276
	T6	9.00-20	955	275	200	0.287

Table 2. Effect of load and inflation pressure on rolling resistance of ADV and automobile discarded tyres

Normal load, daN	ADV tyres					Automobile discarded tyres		
	Inflation pressure, kPa	Rolling resistance, daN				Inflation pressure, kPa	Rolling resistance, daN	
		T ₁	T ₂	T ₃	T ₄		T ₅	T ₆
200	172.5	38.16	32.26	21.75	17.95	69	20.44	12.25
	241.5	40.32	35.19	23.89	23.22	138	20.80	18.28
	310.5	45.28	40.20	30.85	25.50	207	22.50	19.23
	379.5	45.68	42.00	30.86	26.22	276	24.20	21.51
	--	--	--	--	--	345	26.02	22.78
400	172.5	78.81	54.61	28.89	25.07	69	30.92	27.92
	241.5	85.17	70.50	52.87	54.49	138	40.75	30.30
	310.5	89.27	77.32	69.39	68.80	207	44.03	42.60
	379.5	89.10	82.64	71.59	69.68	276	46.50	47.16
	--	--	--	--	--	345	46.17	48.30
600	172.5	90.28	78.42	50.42	58.08	69	41.82	33.91
	241.5	140.73	98.51	81.96	86.06	138	52.07	42.75
	310.5	116.06	106.83	93.78	96.33	207	67.26	52.72
	379.5	121.56	116.50	99.96	103.73	276	79.94	65.38
	--	--	--	--	--	345	83.71	68.68
800	172.5	--	--	65.78	75.79	69	50.22	47.73
	241.5	--	--	96.47	102.17	138	57.99	51.57
	310.5	--	--	111.23	117.56	207	90.27	74.45
	379.5	--	--	124.68	130.24	276	115.71	75.38
	--	--	--	--	--	345	117.84	77.23
1000	172.5	--	--	76.52	85.64	69	65.20	65.20
	241.5	--	--	106.87	109.10	138	69.80	65.69
	310.5	--	--	122.05	126.68	207	89.03	82.22
	379.5	--	--	130.67	132.65	276	121.80	94.06
	--	--	--	--	--	345	122.60	95.76

(200-400 daN), while at higher loads (600-1000 daN), it was indicated by tyre T₃ (50-130 daN) in the range of inflation pressures studied.

The overall performance of T₃ was better than that of other three tyres. The minimum and maximum values of rolling resistance were in the range of 21-76 daN and 30-130 daN, respectively, for the test parameters

used in the study. The results indicated that the upper range of the minimum rolling resistance of the tyre T₃ is 76 daN which is beyond the draft capacity of a single camel (80-100 daN) generally employed to pull a two wheeled cart. The maximum loading capacity for T₃ is therefore, recommended to be less than 600 daN in sandy terrain.

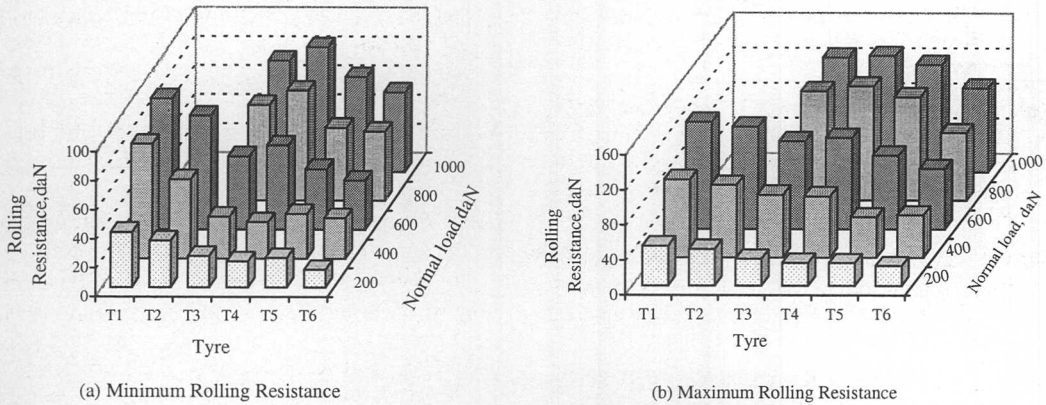


Fig. 2. Comparative performance of tyres in sand.

Performance of automobile discarded tyres

In general, the rolling resistance increased with load and inflation pressure for both tyres (Table 2). It was also observed that the rolling resistance of the buffed tyre was, in general, 5 to 40% lower than that of unbuffed tyre. However, at maximum load of 1000 daN and inflation pressure of 345 kPa the difference in rolling resistance was comparatively low probably due to reduced flexibility of buffed tyre at higher inflation pressure. It is in confirmation with findings of Young *et al.* (1978) and Wong (1984). The main effects of tyre, inflation pressure and load were highly significant on rolling resistance.

Comparative performance of different tyres

The performance of the tyres T₁ and T₂ was the worst among the lot as these tyres showed very high rolling resistance and could not withstand the normal load beyond 600 daN due to excessive deflection (Fig. 2). Out of the remaining four tyres,

the overall performance of buffed tyre (T₆) was better than that of the other tyres. Considering the minimum and maximum values of rolling resistance presented in Figs. 3a and 3b, it is noticed that at the highest normal load of 1000 daN, tyre T₆ indicated 27-56% lower rolling resistance than that of other tyres (T₁, T₂, T₃, T₄, and T₅). In view of the superior performance of tyre T₆, its use is recommended for camel carts on sandy terrains.

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