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Comparative performance evaluation and wear pattern study of rubber liner on the iron wheels of a modified steel bullock cart on tar and earthen roads of rural Odisha

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ABSTRACT : An improved steel bullock cart (2.0 tones capacity) of INSDAG (Institute of Steel Development and Growth, Kolkata) design has been evaluated after putting rubber liner on its iron wheels as a modification, with a view to study its suitability in preventing damage to the surface of rural roads. The experiments were conducted during the year 2012 for the steel cart with rubber liner both in tar and earthen roads of Central Farm, Orissa University of Agriculture and Technology, Bhubaneswar, Odisha. The cart was tested with a pair of non-descript small size bullocks having a pair body weight of 420 kg. Small size bullocks were chosen for the study as bullock cart is still used as a mode of rural transport in tribal dominated areas of the state of Odisha where small size bullocks are mostly available. The results indicated that the small size bullocks could sustain pulling the pay loads of 1200 kg and 1000 kg continuously for three hours in tar and earthen road, respectively with the work rest cycle of 1 hour work + 15 min rest + 1 hour work + 20 min rest + 1 hour work. The draft and power requirement were found to be less and the corresponding speeds to be more in case of tar road compared to the earthen road. There was no significant difference in percentage of wheel slippage between tar and earthen road conditions. The cart was found to be working nicely without damaging the road. At the sustainable load, the wear per cents of rubber liner were more in earthen road than the tar road. The rubber liner can be used safely in the steel cart for about 550 and 220 hours in tar and earthen road, respectively without damaging the surface of road before its replacement. The cost of the rubber liner used in both the wheels of the cart was Rs. 1000/- @ Rs. 40/- per feet length. It is, therefore, concluded that steel cart with rubber liner on its iron wheels is suitable and cost effective for sustainable rural transport.

KEY WORDS : Steel bullock cart, Rural transport, Bullock power, Earthen road

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Bullock cart is still in existence in rural areas of India, mostly in the regions dominated by tribal people where it is used as a mode of transport for small and even medium distance for carrying the agricultural inputs and produce to the nearby markets (Anonymous, 2012). The prediction of Ramaswamy during 1980 regarding the existence of bullock cart in India for years to come remained true even today (Ramaswamy, 1979). Use of bullock cart will also remain in existence in tribal populated areas for long future due to the predominance of bullock farming system and poor socio-economic condition of the people (Srivastava, 2000). It has been estimated that there are at present 15 million bullock carts in India, out of which 80 % are of conventional type (Ghosal *et al*., 2012). The prime limitations of the traditional carts are their low pay load capacity, lack of standard design, poor stability and lack of proper alignment between the yoke and the platform (Ramanujam, 1993). An improvement of the traditional bullock cart with steel frame and pneumatic tyre has proved better with respect to draft and power requirements (Deshpande and Ojha, 1985). Keeping in view of the importance and need of cart mechanization in near future particularly for tribal dominated areas and in rural sectors, one organization namely, Institute of Steel Development and Growth (INSDAG), Kolkata has designed and developed an

improved steel bullock cart for higher pay load, stability and more comfort to the bullocks compared to conventional bullock cart (Anonymous, 2005). The cart of INSDAG make has been designed to carry higher load *i.e.* about 2 times of the existing wooden cart. Its lubrication system with bearing in the wheel, simplicity in construction, increased durability, lighter weight, provision of braking system have made it more attractive for the users. A village artisan can easily manufacture and repair after receiving a preliminary training. However, there is the need to evaluate the performance of the above cart for locally available working bullocks before the same is recommended for adoption. The performance of the steel cart of 2.0 tonnes capacity was found to be satisfactory for medium size bullocks of Odisha both for earthen and tar road (Ghosal *et al*., 2011). The information on the suitability of steel cart of 2.0 tonnes capacity for small size bullocks of Odisha is not available although it is quite important for tribal areas where non-descript small size draft bullocks are the major source of farm power. Almost all farmers among the tribal community are of small and marginal category as per 2011 census and bullock based farming is predominantly followed for performing various agricultural operations. Out of three local non-descript breeds of bullocks namely Ghumsari, Binjharpuri and Mottu existing in Odisha, Mottu breed is the smallest size of bullocks and found in the tribal districts of the state (Behera *et al*., 2006). The pair weight of Mottu breed of bullock varies from 350-500 kg (Anonymous, 2010). Studies (Ghosal *et al*., 2011) on the performance of steel cart (2.0 tonnes capacity) of INSDAG design revealed that the existing rural road conditions (earthen and kutcha road) were found unsuitable for long hours of use due to high friction between the metallic rim and the road surface causing partial damage to the track as well as wheel. Hence, it was felt necessary to put a rubber liner on the iron wheels of the cart, as a modification, in order to prevent the damage to the surface of the rural road. The present study was, therefore, taken up to evaluate the suitability of steel cart of 2.0 tonnes capacity for small size bullocks of Odisha both under earthen and tar road conditions and to assess the feasibility of using rubber liner from wearing point of view.

METHODOLOGY

The two-wheeled steel cart (2.0 tonnes capacity) developed by the Institute of Steel Development and Growth (INSDAG) and fabricated by M/S Viswakarma Fabricators, Aska, Ganjam, Odisha has been procured for the study. The iron wheels of the steel cart have been modified by putting rubber liner around their periphery to protect the road from damage by iron wheels alone. The rubber material was collected from the middle portion of an old and rejected tyre of the truck and its thickness was 1 inch. The cost of rubber liner for both the wheels was Rs. 1000/- (@ Rs. 25/- per feet for 40 feet long liner). The study was conducted during the year 2012 in the Central Farm of OUAT, Bhubaneswar where both tar and earthen roads exist. The specifications of steel cart have been mentioned in Table A. The photographs of steel cart without and with rubber liner are shown in Fig. A and B, respectively.

Table A : Specifications of two wheeled steel cart (2.0 tonnes capacity) pulled by a pair of bullocks

Sr. No.	Components	Dimension
1.	Wheel diameter (mm)	1500
2.	No. of spokes in wheel	18
3.	Axle diameter (mm)	40
4.	Axle length (mm)	1750
5.	Platform size (mm x mm)	3100 x 1000
6.	Yoke length (mm)	1700
7.	Height of platform from ground (mm)	1000
8.	Length of cart (from rear to yoke) (mm)	5200
9.	Ground clearance (mm)	80
10.	Distance between wheels (mm)	1480
11.	Pay load carrying capacity, tonne	2.0
12.	Weight (kg)	280
13.	Wheel bearing	Roller type
14.	Brake	Shoe type
15.	Cost (Rs.)	17,000

Fig. A : two wheel steel cart (2.0 tones capacity) without rubber liner on its wheel

Standard techniques were used for measurement of the different parameters to study the performance of the cart. The experiment was conducted at three hours for each payload and the following observations were taken in one hour interval. Ten points were marked on each wheel of the cart in order to measure the wear during the experiment. The wears in the rubber liner were measured with the help of vernier calipers at each pay load after three hours of running the cart. Mean values of percentage of wear were finally calculated by taking

Fig. B : Two wheel steel cart (2.0 tones capacity) with rubber liner on its wheel

the data of ten points for each wheel in every experiment. The modified cart has been evaluated with the help of two non-descript small size bullocks (pair weight 420 kg) commonly available in the tribal districts of Odisha.

Observations:

– Pay load, kg
– Draft, N
– Forward speed (m/s)
– Wheel slippage (%)
– Physiological responses of bullock (pulse rate, respiration rate, body temperature).
– Fatigue score.

Wear pattern (decrease in thickness) of rubber liner used in both the iron wheels.

RESULTS AND DISCUSSION

The experimental findings obtained from the present study have been discussed in following heads:

Evaluation of steel cart with rubber liner on its wheels under both tar and earthen road conditions:

The cart was evaluated with rubber liner on its wheels by the small size bullocks of Odisha under both tar and earthen road conditions. In the first phase, the performance of the cart was studied for nine days in tar road with the change of pay loads ranging from tare to 1300 kg. The work rest cycle of 1 hour work + 15 min rest + 1 hour work + 20 min rest + 1 hour work was followed during the test period. The total hours of operation were 25 for 3 hours of use in a day for eight days and only 1 hour in the ninth day as the bullocks got fatigue after one hour of running of the cart with the pay load of 1300 kg. In the second phase, the performance of steel cart with rubber liner was studied for the same small size bullocks and the same work rest cycle in earthen road condition with the change of pay loads ranging from tare to 1100 kg. The total hours of operation were 19. The fatigue score, corresponding to different pay loads during the test period indicated to limit the test up to pay loads of 1300 kg and 1100 kg in tar and earthen road, respectively. Therefore, the duration of test was restricted accordingly. The results of the experiment conducted for the various pay loads in case of tar and earthen roads are presented in Tables 1 and 2, respectively and in Fig. 1 to 3.

The results indicated that the average draft increased from 107.91 N to 441.45 N when pay loads increased from tare weight to 1300 kg in case of tar road as against the average drafts from 147.15 to 431.64 N with increase of pay loads from tare weight to 1100 kg for earthen road. The average speeds were found to decrease from 3.96 to 2.41 kmph from tare weight to 1300 kg in case of tar road as against the same from 3.6 to 2.41 kmph with increase of pay loads from tare weight to 1100 kg for earthen road. Similarly, the power requirements increased from 0.11 to 0.29 kW when pay loads increased from tare weight to 1300 kg in case of tar road as against the same from 0.147 to 0.289 kW with increase of pay loads from tare weight to 1100 kg for earthen road. The average wheel slippage percentage decreased from 0.40 to 0.20 when pay loads increased from tare weight to 1300 kg in

Table 1 : Performance of steel bullock cart (2.0 tones capacity) with iron wheel with rubber liner pulled by a pair of small size bullocks on tar road

Sr. No.	Pay load (kg)	Av. draft (kg)	Av. draft (N)	Draft, (%) of body weight	Av. speed (m/s)	Av. speed (km/h)	Av. power, requirement (kW)	(%) Av. wheel slippage	Fatigue score
1.	Tare (280+50)	11	107.91	2.61	1.1	3.96	0.11	0.40	6
2.	400	19	186.39	4.52	1.0	3.6	0.18	0.36	8
3.	600	23	225.63	5.47	0.87	3.13	0.19	0.32	10
4.	800	32	313.92	7.61	0.80	2.88	0.25	0.30	12
5.	900	37	362.97	8.80	0.77	2.77	0.27	0.26	15
6.	1000	39	382.59	9.28	0.75	2.7	0.28	0.23	16
7.	1100	40	392.4	10.5	0.73	2.62	0.286	0.22	18
8.	1200	42	412.02	10	0.71	2.55	0.29	0.21	19
9.	1300	45	441.45	10.71	0.67	2.41	0.29	0.20	23

Table 2 : Performance of steel bullock cart (2.0 tones capacity) with iron wheel with rubber liner pulled by a pair of small size bullocks on earthen road

Sr. No.	Pay load (kg)	Av. draft (kg)	Av. draft (N)	Draft, (%) of body weight	Av. speed (m/s)	Av. speed (km/h)	Av. Power, requirement (kW)	(%) Av. wheel slippage	Fatigue score
1.	Tare (280+50)	15	147.15	3.57	1.0	3.6	0.147	0.36	8
2.	400	21	206.01	5	0.97	3.492	0.199	0.34	10
3.	600	25	245.25	5.95	0.92	3.312	0.225	0.31	12
4.	800	35	343.35	8.33	0.77	2.772	0.264	0.27	15
5.	900	40	392.4	9.52	0.74	2.664	0.290	0.25	17
6.	1000	42	412.02	10	0.70	2.52	0.288	0.23	19
7.	1100	44	431.64	10.47	0.67	2.412	0.289	0.21	21

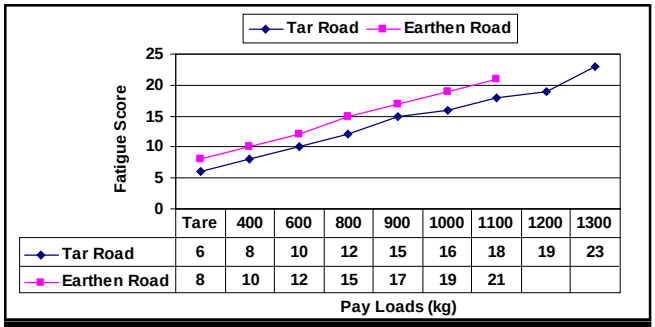

Fig. 1 : Comparative fatigue scores of bullocks for steel cart of iron wheels with rubber liner on tar and earthen road

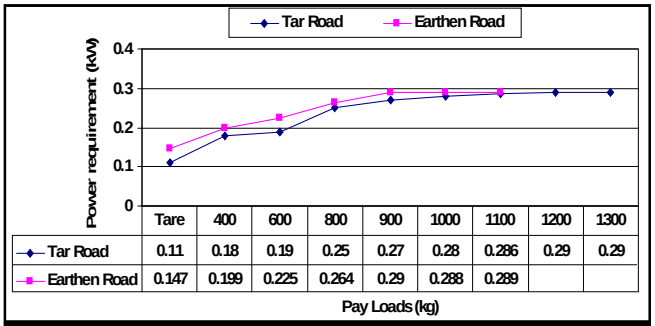

Fig. 2 : Comparative power exerted by bullocks for steel cart of iron wheels with rubber liner on tar and earthen road

case of tar road as against the same from 0.36 to 0.21 with increase of pay loads from tare weight to 1100 kg for earthen road. It was found that non-descript small size bullocks could sustain pulling 1200 kg and 1000 kg pay loads for three hours of use of the above cart on the tar and earthen road, respectively as the final fatigue score reached to 19, just below the threshold fatigue level of 20 (Upadhay and Madan, 1985). With further increase of pay loads, the fatigue score exceeded to 20.

Wear pattern study of rubber liner for both the wheels of steel cart on tar and earthen road:

While studying the performance of cart with the wheels having rubber liner, the wears (decrease in thickness of rubber liner) of both the wheels were measured on hourly basis with respect to increased pay loads and time. But the mean percentage wears of rubber liner for both the wheels at each pay load after 3 hours of use both in tar and earthen road have been mentioned in Table 3. The total hours of operation of the same cart were 25 for nine days in case of tar road followed by 19 hours for seven days in earthen road. Thereafter, the wear patterns of rubber liner were studied for the sustainable loads of 1200 kg for tar road followed by 1000 kg for earthen road. The experiments with the sustainable loads for both the tar and earthen road were conducted for seven days each with 3 hours of use in a day and the data are placed in Table 4.

Table 3 : Wear pattern (decrease in thickness) of rubber liner on iron wheels of 2.0 tonnes capacity steel bullock cart on tar and earthen road

Sr. No.	Payload (kg)	Mean percentage wear of rubber liner for both wheels after 3 hours of use on tar road	Mean percentage wear of rubber liner for both wheels after 3 hours of use on earthen road
1.	Tare (280 + 50)	0.248	0.423
2.	400	0.347	0.528
3.	600	0.421	0.601
4.	800	0.486	0.665
5.	900	0.528	0.704
6.	1000	0.566	0.751
7.	1100	0.583	0.807
8.	1200	0.601	
9.	1300	0.605	

Table 4 : Wear pattern (decrease in thickness) of rubber liner on iron wheels of 2.0 tonnes capacity steel bullock cart at a sustainable loads of 1200 kg on tar road and 1000 kg on earthen road

Day of experiment (3 hours use in each day)	Total hours of use (hr)	Mean percentage wear of rubber liner for both wheels after 3 hours of use in each day for tar road	Mean percentage wear of rubber liner for both wheels after 3 hours of use in each day for earthen road
1st	3	0.634	0.664
2nd	6	0.638	0.725
3rd	9	0.661	0.769
4th	12	0.667	0.798
5th	15	0.688	0.855
6th	18	0.702	0.889
7th	21	0.723	0.930

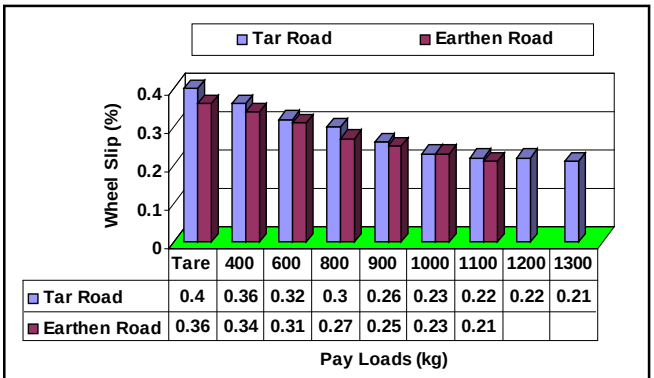

Fig. 3 : Comparative wheel slippage percentage for steel cart of iron wheels with rubber liner on tar and earthen road

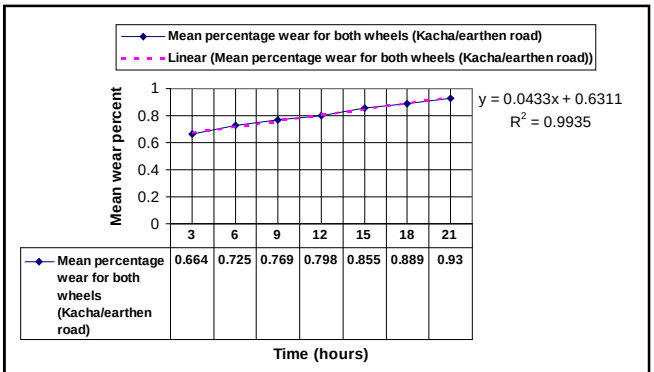

Fig. 4 : Mean per cent wear of rubber liner for both the wheels of steel bullock carts at sustainable load of 1200 kg on tar road

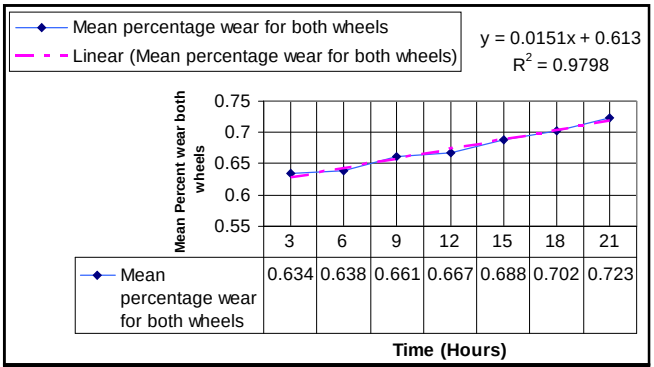

Fig. 5 : Mean per cent wear of rubber liner for both the wheels of steel bullock carts at sustainable load of 1000 kg on earthen road

The thickness of rubber liner at ten different points for each wheel was measured on hourly basis and finally the mean per cent wear from initial stage to third hour of operation was calculated for both the wheels. Mean percentage wears of rubber liner for both wheels after 3 hours of use in a day on tar road were observed to be from 0.248 to 0.605 with pay loads ranging from tare to 1300 kg. Similarly, the mean per cent of wears were from 0.423 to 0.807 with pay load ranging from the same tare to 1100 kg for earthen road. The small size bullocks of Odisha were found pulling the sustainable loads of 1200 kg and 1000 kg for three hours continuously with the above work rest cycle on the tar and earthen road, respectively. The mean per cent wears of rubber liner for both the wheels of steel bullock cart at the sustainable load in tar and earthen road have been shown in Fig. 4 and 5, respectively.

At the sustainable load of 1200 kg, the mean per cent of wears for both the wheels were observed to be varying from 0.634 to 0.723 in tar road with about 14 % increase of wear from 1st day to 7th day. Similarly, at the sustainable load of 1000 kg, the mean per cent of wears for both the wheels were observed to be varying from 0.664 to 0.930 in case of tar road with about 40 % increase of wear from 1st day to 7th day. The wear per cents of rubber liner were found to be more in earthen road compared to tar road. This may be attributed to the more unevenness of earthen surface and more friction between the surface and rubber liner in the earthen road. The predicted equations for the variation of mean per cent of wear with the time of operation for both the wheels at the sustainable loads for tar and earthen road have been derived to calculate the per cent of wear with the use of the rubber liner for its replacement. Allowing about 10 per cent wear of rubber liner (Kravckenko *et al*., 2012) for safe use before replacement, it

can be used for about 550 and 220 hours with the steel cart on tar as well as earthen road, respectively without affecting the surface of the track.

Conclusions:

The steel bullock cart (2.0 tonne capacity) has been tested with a pair of non-descript small size bullocks of Odisha having pair body weight of 420 kg both in tar and earthen road conditions after modifying the periphery of its iron wheels with rubber lining. The work rest cycle followed was 1hr work + 15 minutes rest + 1 hr work + 20 minutes rest + 1 hr work. The cart was found to be working nicely without damaging the road. The small size bullocks could sustain pulling only 1200 kg and 1000 kg pay loads for three hours of use in the tar and earthen road, respectively. At the sustainable load, the wear per cents of rubber liner were more in earthen road than the tar road. The rubber liner can be used safely in the steel cart for about 550 and 220 hours in tar and earthen road, respectively without damaging the surface of road before its replacement. The cost of the rubber liner used in both the wheels of the cart was Rs. 1000/- @ Rs. 40/- per feet length. It is therefore concluded that steel cart with rubber liner on its iron wheels is suitable and cost effective for sustainable rural transport

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