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Chain Drive Steering Mechanism for a Four Wheeler

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Abstract: Steering is one of the essential requirements of an automobile. This mechanism should be capable of giving correct steering. Incorrect steering mechanism may cause skidding of the tires on the road, leading to excess wear, noise and reduction in life of tires. In this paper an effort is made to develop a steering mechanism using chain drive which may substitute the Ackermann mechanism. This mechanism is entirely mechanical, simple, trust worthy and gives better steering.

Keywords: Steering Mechanism, Correct Steering, Chain Drive, Bell crank lever.

I. INTRODUCTION

Steering is one of the most important systems of an automobile. It should be capable of giving correct steering. Incorrect steering may cause skidding of the tires on the road, leading to excess wear, noise and reduction in life of tires. The steering system allows the driver to guide the moving vehicle on the road and turn it right or left as desired. It has been a common practice to provide steering only to front wheels. In fact steering may also be provided only to rear wheels or to all the four wheels. A perfect steering mechanism should ensure that when the axes of rotation of all the four wheels are extended, they should intersect at one point. With this point as centre, the automobile would take a smooth turn in a circular path. If the steering is given only to front wheels, the perfect steering condition may be restated as when the axes of the two front wheels are extended they should intersect at a point on the common rear wheel axis. This is shown in Fig. 1. Using simple geometric principles the condition for perfect steering may be expressed mathematically as

$$\cot\theta - \cot\text{ø} = W/H \qquad (1)$$

where, θ and ø are angles through which the outer and inner stub axles are turned. W and H are called track width and wheel base, respectively. W and H denote the main physical dimensions of the vehicle. Equation (1) shows that the angles through which the stub axles are turned are related to physical dimensions of the vehicle.

It is also to be observed that the angle ø through which the inner stub axle is turned is more than the angle θ through which the outer stub axle is turned.

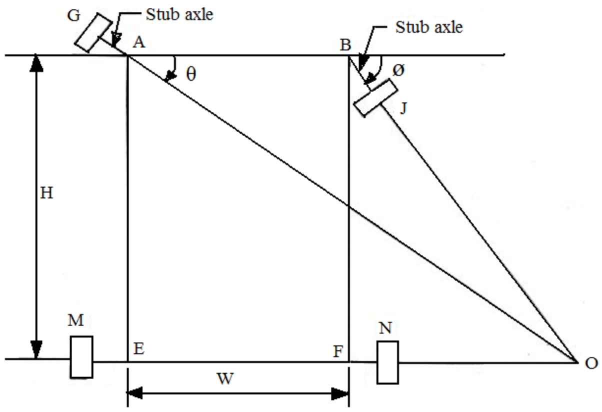

Fig. 1. A car taking right turn

One mechanism which ensures correct steering always is Davis mechanism [1]. This is shown in the Fig.2.

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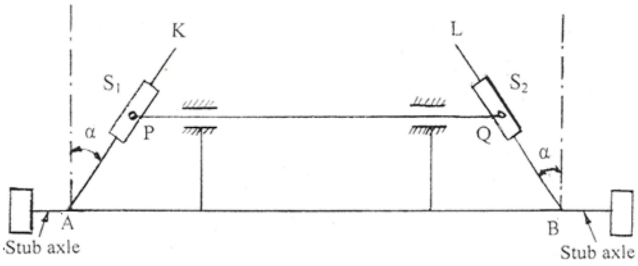

Fig.2. Davis steering mechanism

It is to be observed that in this mechanism, three prismatic pairs are involved. It is difficult to move the links in this mechanism because of practical difficulty posed by the prismatic pairs. In order to avoid such difficulties, an Ackermann mechanism is used, which is shown in the Fig.3.The Ackerman mechanism is essentially a four bar mechanism ABDC. Links AC and BD are called track arms. Link CD is called track rod. Links AC and BD extended up to G and J, respectively, forming two bell crank levers GAC and JBD. AG and BJ are the stub axles on which the front wheels are free to rotate.

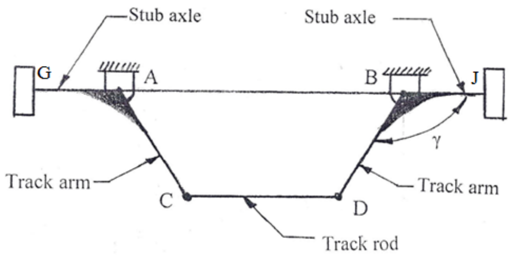

Fig. 3. Ackermann steering mechanism

The mechanism consists of two bell crank levers GAC and JBD which are hinged to chassis at points A and B, respectively. The actual mechanism ABDC is a four bar mechanism. When the mechanism is operated, it may occupy a position such as ABD'C' as shown in Fig. 4. Clearly, it is not a perfect steering.

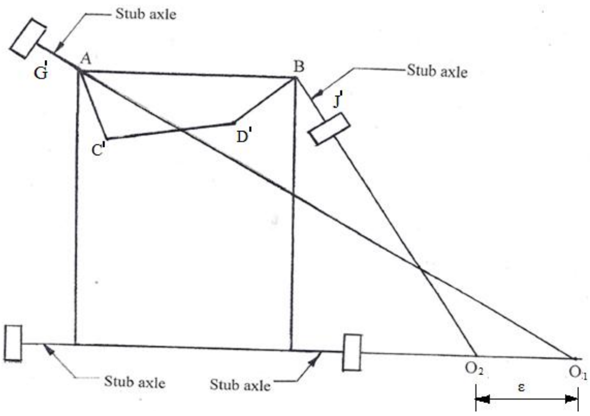

Fig.4. Steering offered by Ackermann mechanism

The study of Ackermann mechanism for modifications and improvements has been subjects of interest for many researches in the past. But they are not available in the published literature, may be because of secrecy.

Friedrich [2] studied the vehicle characteristics and steering control quality through theoretical dynamic analysis and experimental investigations. Schneeweish [3] gave dependence of front wheel drive concepts on the position of engine transmission. Daniel [4] studied caster and steering geometry together. Shibahata et al. [5] described the development of four wheel steering where the rear wheels are controlled electronically in addition to front wheel steering. Sano et al. [6] also studied the concept of steering of rear wheels as a function of steering of front wheels. Rahamani Hanzaki et al. [7] made a study on combined kinematic and sensitivity optimization of a rack and pinion steering linkage.

Tapp [8] studied simultaneous steering of all the four wheels using two Ackermann mechanisms; one for the front wheels and other for the rear wheels. These two mechanisms are coupled through a variable length lever. Bruce Maclaurin [9] described a model for the steering performance of a tracked vehicle that allows for deformation

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characteristics of rubber track pads. Kamner [10] suggested steering system for vehicles having pivotally inter connected frames with at least one set of steerable wheels.

As an alternative, one may think of having a dedicated microprocessor which senses the angle of the turn of one front wheel, calculate the required angle of turn of another front wheel, and send a signal to a motor which rotates the other front wheel by the required angle by applying sufficient of torque. However, there are practical difficulties such as response being slow and the drive not being positive. That is, the motor may apply the torque to turn the front wheel but the wheel may not turn because of any obstructions offered by the stones or loose soil present between the road and tires. Further, the electronic components may not offer reliable service. A mechanical means would be reliable and can provide a positive drive.

In this paper an effort is made to replace the Ackerman mechanism with a simple chain drive arrangement which can also provide a positive steering drive.

II. DESCRIPTION OF MECHANISM

Fig. 5 shows the description proposed mechanism. It consists of two sprockets which can rotate about the pivot points A and B. The stub axles of the front wheels are integral parts of these sprockets. The rotations of these two sprockets are coupled using a chain drive. Let R_A and R_B be the radii of the two sprockets.

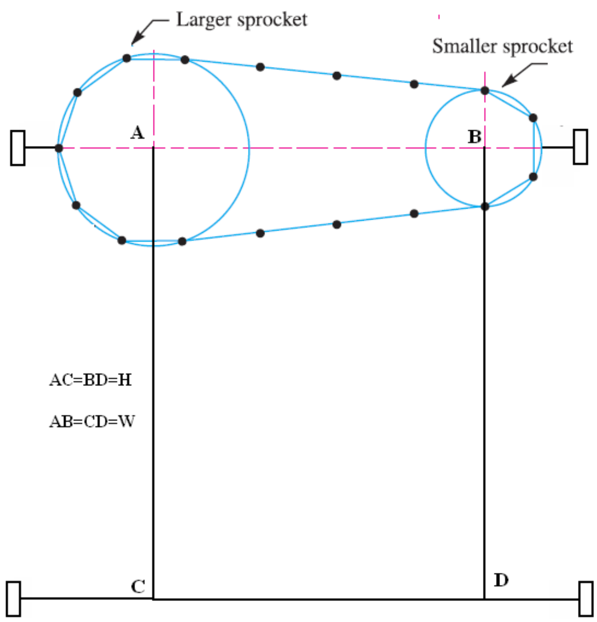

Fig. 5. Steering mechaniosm with chain drive

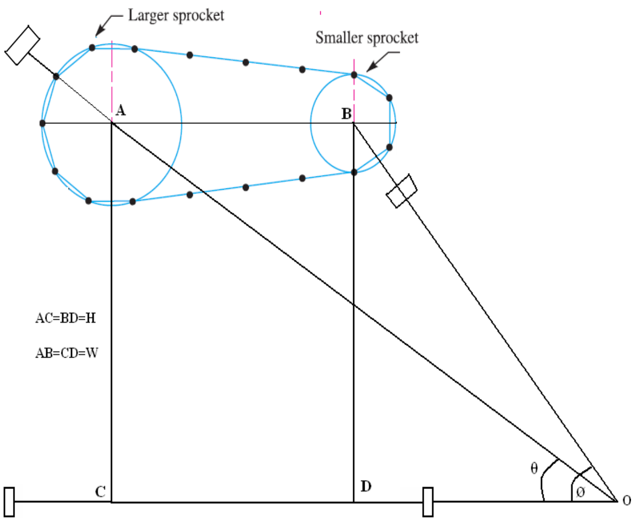

Fig. 6. Steering mechaniosm taking right turn with chain drive

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Fig. 6 shows the two stub axles being rotated through angles θ and ø and satisfying the condition for correct steering. The standard dimensions of Santro car are taken for the purpose of analysis. W and H are measured to be 1360 mm and 2380 mm, respectively. For these values of W and H, the values of θ and ø are computed using Equation (1) and are already tabulated in Table 1. The maximum angle through which the outer wheel turns is observed to be around 30˚. Accordingly, the maximum value of θ is limited to 30˚ only.

From the values listed in Table 1, it is observed that for a total rotation of 30˚ of the outer stub axle, the inner stub axle undergoes a total rotation of 40.738˚. This can be accomplished using a chain drive shown in the proposed mechanism. For the sake of analysis the dimensions of the chain drive are taken as follows:

Number of teeth on small sprocket (T_A) = 20
Pitch of the chain (p) = 10 cm

The radii of the two sprockets may now calculated with simple formulae [1] and are related as

$$R_B / R_A = 0.852 = \theta^* / ø \qquad (2)$$

This ensures that when the inner stub axle rotates through 40.738˚, the outer stub axle rotates through 30˚. It is not guaranteed that the correct steering is satisfied throughout. Therefore, it is a matter of

III. ANALYSIS OF THE PROPOSED MECHANISM

To observe the performance of the proposed mechanism, the inner stub axle angle ø is varied in steps of 1˚ and the corresponding values of the angles θ* through which the outer stub axle is turned by the proposed mechanism, are obtained. These values are tabulated in the Table 1.
The table also shows the difference Δθ between the desired value of θ for correct steering and the value θ* given by the present mechanism. The percentage error e, the steering error ε and the sliding error parameter $K_o$are also calculated and tabulated in Table 1.

The variation of values of θ, θ*, Δθ, e, ε, $K_o$with ø is shown in Fig.7. One may attempt to do a similar analysis with a different value for radius R_A and R_B.

IV. RESULTS AND DISCUSSIONS

Fig.7a shows the variation of θ and θ*. The mechanism proposed is giving a value θ* which is less than the desired value θ and more than the desired value θ. However, θ and θ* are same at two points. The proposed mechanism certainly does not give correct steering except at the two positions.

Fig. 7b shows the variation of Δθ with ø. A maximum value of Δθ is noticed when ø is 8.68˚. The maximum difference is around 1˚. This much of inaccuracy may be tolerable, as a reasonably accurate steering could be achieved through this arrangement.

Fig. 7c shows the variation of percentage error in θ. Maximum percentage error of 14% is occurring in the beginning and is gradually reducing towards the end.

Fig. 7d shows the steering error ε. The steering error is maximum in the beginning and is decreasing very rapidly to zero in 10˚ turn of the front wheel.

Fig. 7e show the variations of parameters K_o with ø. This parameter describes the sliding velocity. The areas under these curves may give an estimate of length of sliding, assume V and (dø/dt) as constants.

$$S = [V / (dø/dt)] \int K_o dø \qquad (3)$$

The integral in the above expression is nothing but the area under the curve. The above expression gives the maximum amount of sliding that can happen to outer front wheel. Similarly the maximum amount of sliding that can takes place for the inner front wheel may also be estimated. For a car moving with 10 km/hr speed and attempting to turn the inner front wheel through 10˚ in 0.1 sec the sliding can be calculated as 0.007 m.

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TABLE1. PERFORMANCE STUDY OF THE PROPOSED MECHANISM

Ø (deg)	θ (deg)	θ* (deg)	Δθ (deg)	e	ε (mm)	K_o
0	0	0	0	---	---	---
1.01	1	0.8585	0.1415	14.15	-22480.1	0.0066
2.04	2	1.734	0.266	13.3	-10446.4	0.0133
3.09	3	2.6265	0.3735	12.45	-6438.14	0.0199
4.16	4	3.536	0.464	11.6	-4436.25	0.0266
5.26	5	4.471	0.529	10.58	-3228.2	0.0332
6.38	6	5.423	0.577	9.616667	-2427.01	0.0397
7.52	7	6.392	0.608	8.685714	-1857.31	0.0462
8.68	8	7.378	0.622	7.775	-1431.87	0.0527
9.87	9	8.3895	0.6105	6.783333	-1099.95	0.0591
11.09	10	9.4265	0.5735	5.735	-834.174	0.0654
12.33	11	10.4805	0.5195	4.722727	-618.471	0.0716
13.59	12	11.5515	0.4485	3.7375	-440.114	0.0777
14.89	13	12.6565	0.3435	2.642308	-288.224	0.0837
16.21	14	13.7785	0.2215	1.582143	-159.399	0.0895
17.55	15	14.9175	0.0825	0.55	-48.9016	0.0952
18.92	16	16.082	-0.082	-0.5125	47.44057	0.1007
20.32	17	17.272	-0.272	-1.6	132.0292	0.1061
21.74	18	18.479	-0.479	-2.66111	206.263	0.1112
23.19	19	19.7115	-0.7115	-3.74474	272.2533	0.1161
24.67	20	20.9695	-0.9695	-4.8475	331.1791	0.1207
26.17	21	22.2445	-1.2445	-5.92619	383.674	0.1251
27.70	22	23.545	-1.545	-7.02273	430.934	0.1292
29.26	23	24.871	-1.871	-8.13478	473.6006	0.1329
30.83	24	26.2055	-2.2055	-9.18958	511.7532	0.1363
32.43	25	27.5655	-2.5655	-10.262	546.4025	0.1392
34.05	26	28.9425	-2.9425	-11.3173	577.732	0.1417
35.70	27	30.345	-3.345	-12.3889	606.2761	0.1437
37.36	28	31.756	-3.756	-13.4143	632.0038	0.1453
39.04	29	33.184	-4.184	-14.4276	655.364	0.1462
40.73	30	34.6205	-4.6205	-15.4017	676.4654	0.1465

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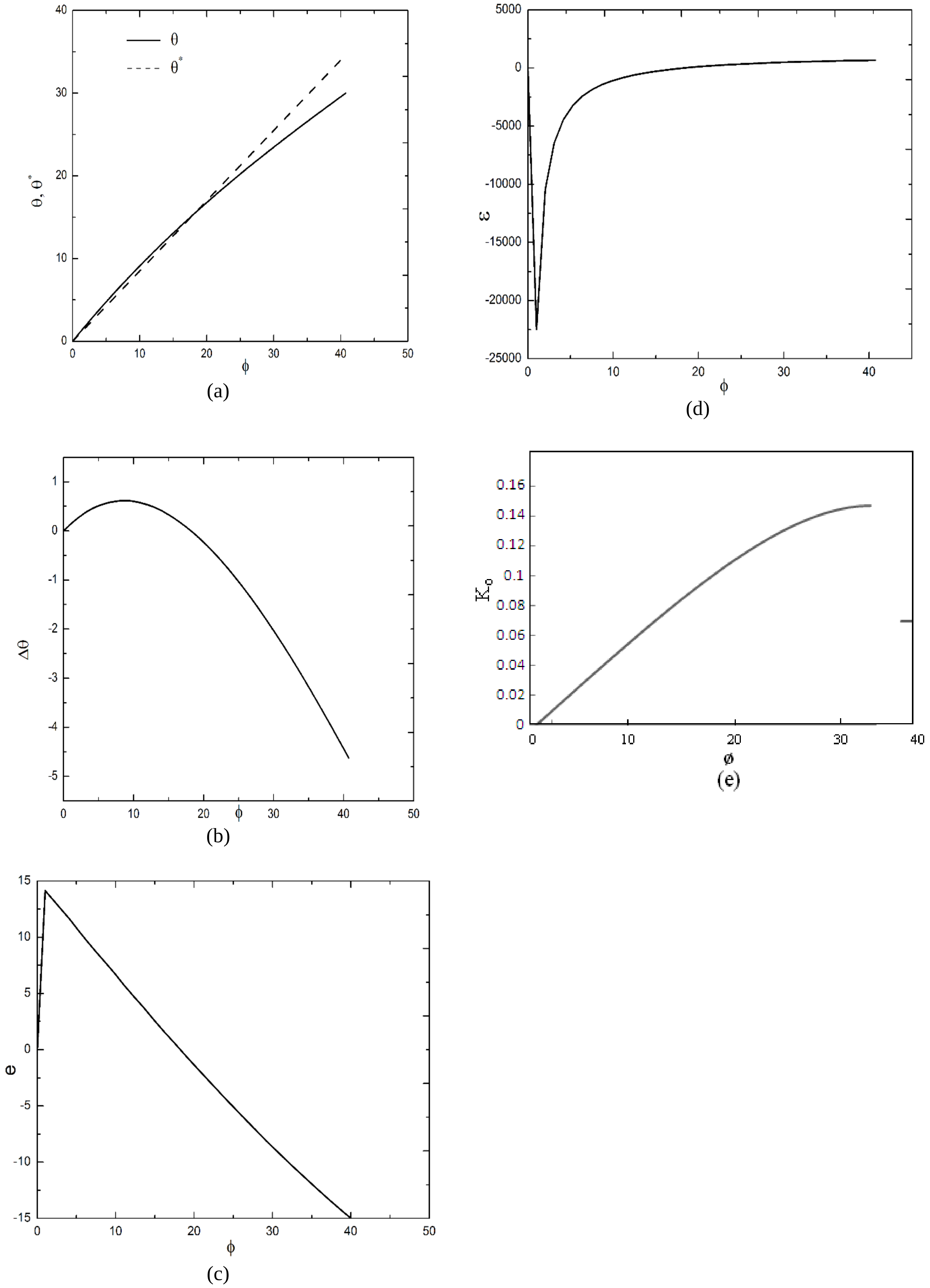

Fig. 6. Analysis of proposed mechanism.

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BIOGRAPHY

Dr. A. Padma Rao was born in Munpally, Armoor, Nizamabad, India, in 1980. He received the B.Tech. degree in Mechanical Engineering from the JNT University of Hyderabad, Hyderabad, India, in 2001, and the M.E. in Mechanical Engineering from the Andhra University College of Engineering, Andhra University, Visakhapatnam, A.P., India, in 2007 and Ph.D. in Mechanical Engineering from National Institute of Technology, Warangal, India, in 2012.Currently working as a professor in Mechanical Engineering Dept., B.V. Raju Institute of Technology, Narsapur, Medak, India. His current research interests include machines design, machines and mechanisms. Dr. A.P. Raois a Member of the Association of Mechanisms, Society of Automotive Engineering. He is a Member of the Indian Society for Technical Education (ISTE). He was the reviewer of different International and National Journals. He is having two patents, published 30 research papers in various journals and conferences.