MECHANISMS FOR THE REAR AXLE STEERING BOX WITH INTEGRAL STEERING

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Abstract: This paper addresses the problem of integral steering that has the rear wheels steering in the same direction to the front wheels, but also in the opposite direction. Simple articulated mechanisms for the rear axle steering box are presented, mechanisms that steer the rear wheels according to the direction of the front wheels, respectively to the rotation angle of the steering wheel. At the begging of a turn, the considered/proposed mechanisms are steering the rear wheels in the same direction to the front wheels, then brings them back to neutral to steer them in the opposite direction. The functionality of the system is analyzed – the extent to which the requirements of the integral steering are met by the considered/proposed mechanisms.

1. INTEGRAL DIRECTION ISSUE

Steering of vehicles with two steering axles can be accomplish by reducing the steering radius (fig.1,b) or increase it (fig.1,c), as the rear wheels are steered in the opposite/same direction to the front ones.

$$r_{v_1} = \frac{L_a}{tg\,\theta_f}, \qquad r_{v_2} = \frac{r_{v_1}}{1 + tg\,\theta_s / tg\,\theta_f}, \qquad r_{v_3} = \frac{r_{v_1}}{1 - tg\,\theta_s / tg\,\theta_f}. \tag{1}$$

The notations from figure and relations are referring to:

L_a - axle base, distance between vehicle axels,

B_p - distance between steering wheels pivots,

O_v - the turning center, normal intersection at the wheels trajectory,

r_v - steering radius - distance from O_v at the vehicle axis;

$\theta_{f,s}$ - the front/rear wheel steering angle.

As the steering radii are:

$$r_{v_2} = \frac{L_a}{tg\,\theta_f + tg\,\theta_s}, \qquad r_{v_3} = \frac{L_a}{tg\,\theta_f - tg\,\theta_s}, \tag{2}$$

aratio $k = \theta_f / \theta_s$ could be maximum $k = 1$ for steering in opposite direction, respectively maximum $k = 0.5$ for steering in the same direction.

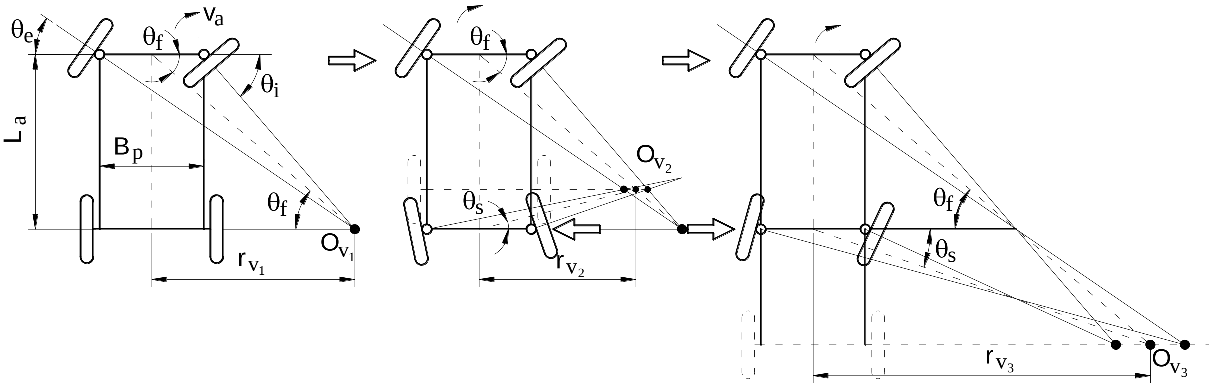


Figure 1. The turning radius and the steering angles for 1/2 steering axle.

It is known/proven [2;6] that the steering of the rear wheels in the opposite direction to the front wheels for increasing maneuverability (reduces radius r_v), leads to decreasing the stability, and the steering in the same direction increases stability but decreases vehicle maneuverability.

The integral steering aims to satisfy both conflicting requirements in an optimal compromise.

As the stability is a crucial parameter for modern high-speed vehicles, we assume that the vehicle enters the curve at high speed, and during the steering, the turn radius, as well as the speed, arereduced.

Thus, in the beginning section of steering, the rear wheels – for a good stability – should steer in the same direction to the front ones; if the steering angleincreases, rear wheels should be reduced to the neutral position and then to be steered in the opposite directions to the front ones – thus, reducing the turning radius. The front/rear steering functions in relation to the steering wheel rotation angle φ_v were presented as in Figure 2 (numerical values are indicative).

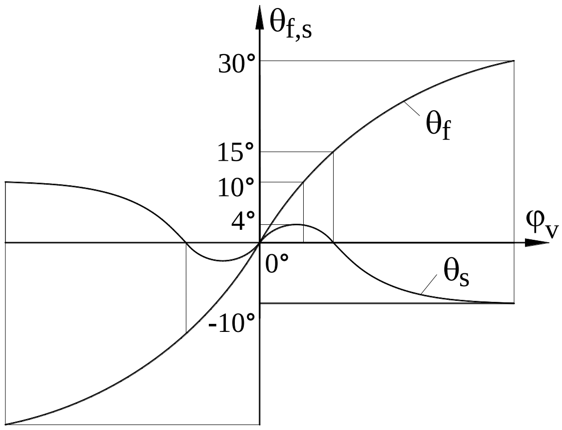


Figure 2. The steering functions for integral steering.

At maneuvers, such as parking, this kind of integral steering makes the driver feel a rather strange behavior: at first, the rear wheels do not seem to “listen” tothe commands.

Basically, the command from the steering wheel operates a central lever 1 (fig.3,a) or a rack 1 (fig.3,b), which steers the front wheels 2-3, simultaneously, the movementbeing transmitted to his correspondent (rack lever 5 or 5) on the rear axle, which will steer the wheels 6-7.

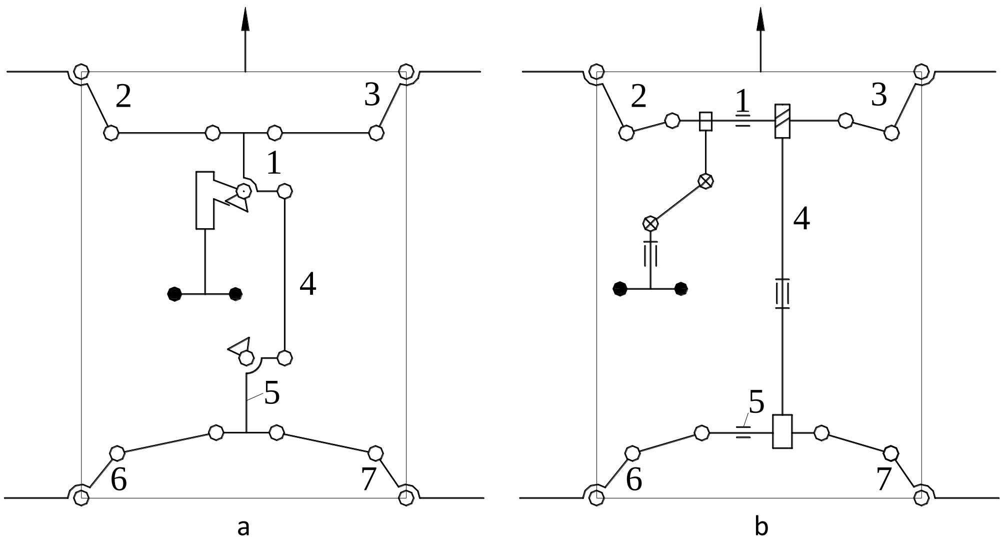


Figure 3. Classical steering mechanisms for front/rear wheels.

The rear axle's steering mechanism must have a special structure to achieve the induced steering function.

Such a structure – articulated by bars – is presented below, beinginterposed between the shaft 4 and rack 5 (2 in fig.4)

2. INTEGRAL STEERING MECANISMS

According to Figure 4, the steering box mechanism for integral steering consists of structure 1- 2 - 3.

To obtain the functions $\theta_s(\varphi_v)$or $\theta_s(\theta_f)$ according to figure 2, is a very difficult task, that requires the imposition of a swing movement with different amplitudes to a central lever 3 or a rack 3, as well asactions' symmetry for left or right steering of the vehicle. Various types of articulated mechanisms for operating the lever/rack are proposed in papers [1,5], but without tangible result for their position. Variants that are acting through cams are proposed in papers [3, 4].

We take into consideration the simple mechanisms with one contour from figure 5,wherehandle 1 receives the movement from longitudinal shaft 4.

These mechanisms - for rear steering box - can achieve a backward-and-forward motion of the central element 3. To achieve symmetry, for left / right steering, they should be positioned to going straight (neutral position, initial resistance) so that the handle to be along the base.

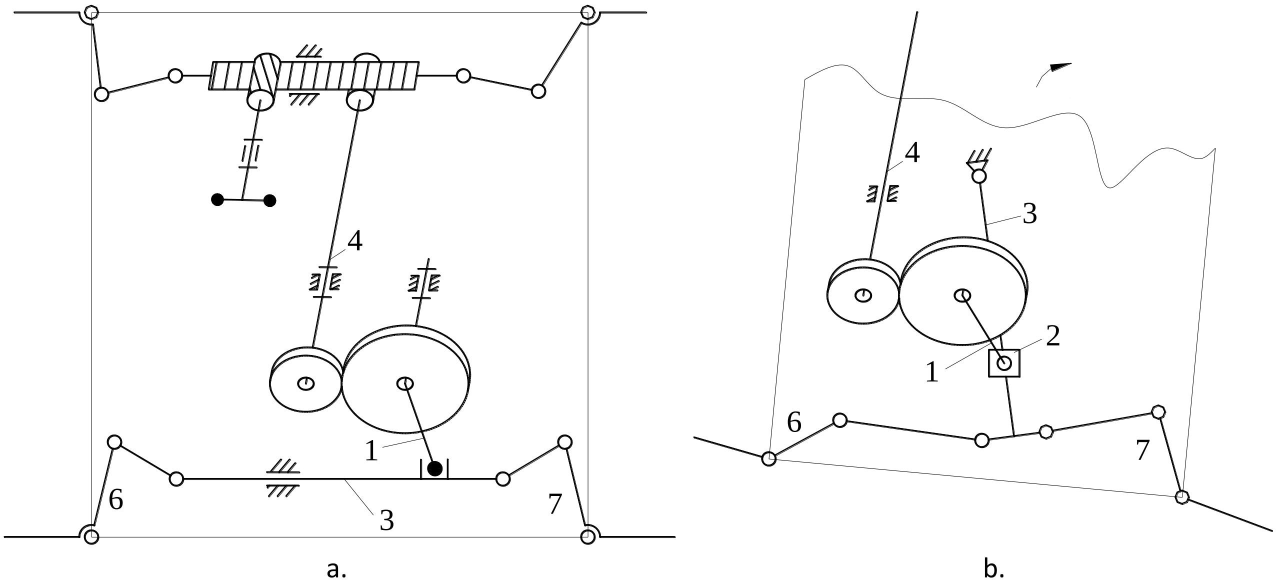
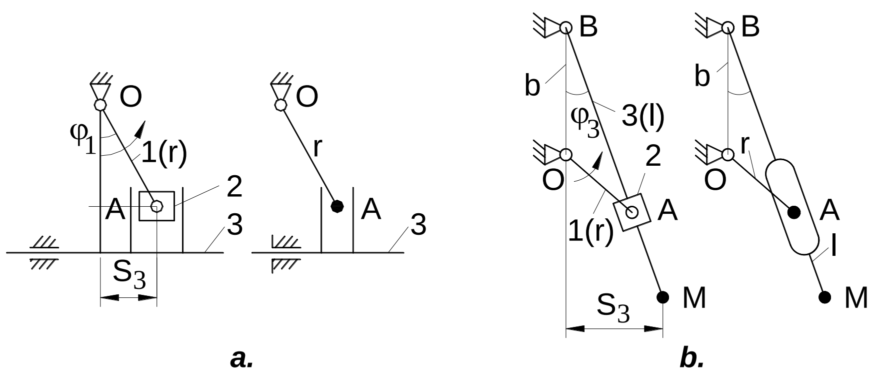
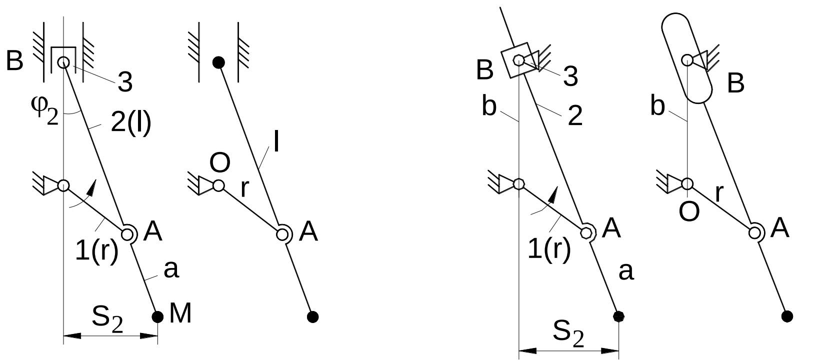


Figure 4. Positioning of integral steering mechanism.



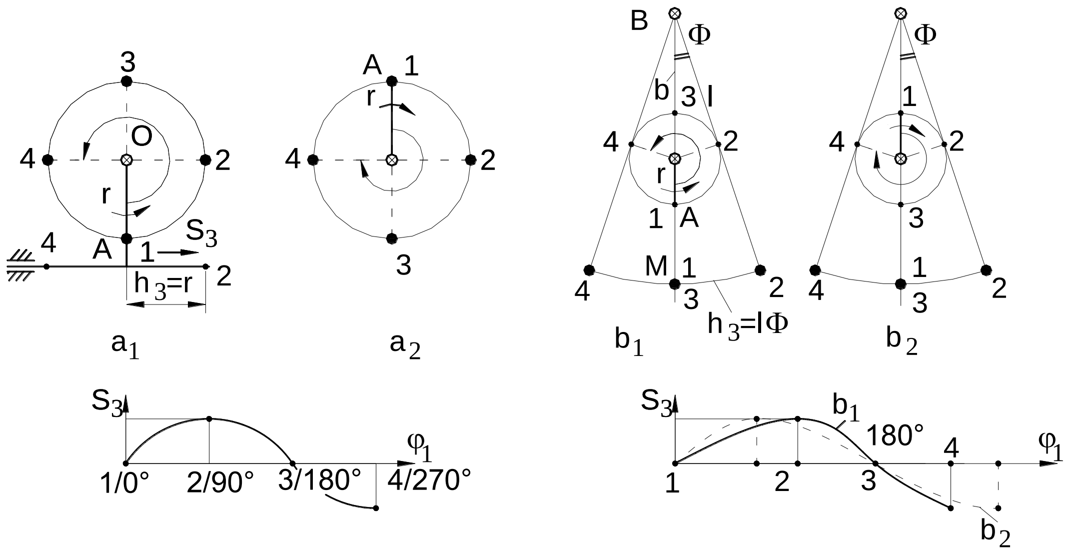


c. *d.*

Figure 5. Single contour mechanism for integral steering.

Therefore, RRTT mechanism (sine, $S_3 = r\sin\varphi_1$) from figure 5,a, should initially be positioned (fig.6,a) with the handle in an inferior position 1 (fig.5,a. 1); by the counterclockwise rotation the function $S_3(\varphi_1)$is obtained and has the shape shown in figure 2. For clockwise rotation, the handle starts from superior position 1 (fig.5,a. 2), in both cases the maximum handle rotation being 270^0. The characteristic positions of the handle are marked by points 1, 2, 3, 4, corresponding to the functional diagram $S_3(\varphi_1)$. The race S_3 is defined by a single geometrical parameter, radius *r* of the handle, making it difficult for optimization.

For RRTR sliding mechanism ($S_3 = l\sin\varphi_3, \varphi_3(\varphi_1)$) from figure 5,b, similarly, the handle OA in the initial position has to be arranged along the line OB of the base, inferior position 1 (fig. 5,b_1) or superior (fig.5,b_2) being correlated with the direction of the handle's rotation. Therefore, from position 1 to 2, the rear wheel will steer in the direction of the wheels in front, followed by returning from position 2 to 3 (when $\varphi_1 = 180°$), and then the rear wheels will steer in the opposite direction from position 3 to 4; in position 4 the maximum steering is achieved – which corresponds to $\varphi_1 = 270° - \Phi$ ($\Phi = \arcsin r/b$), respectively $\varphi_1 = 270° + \Phi$ for b_2.



a. *b.*

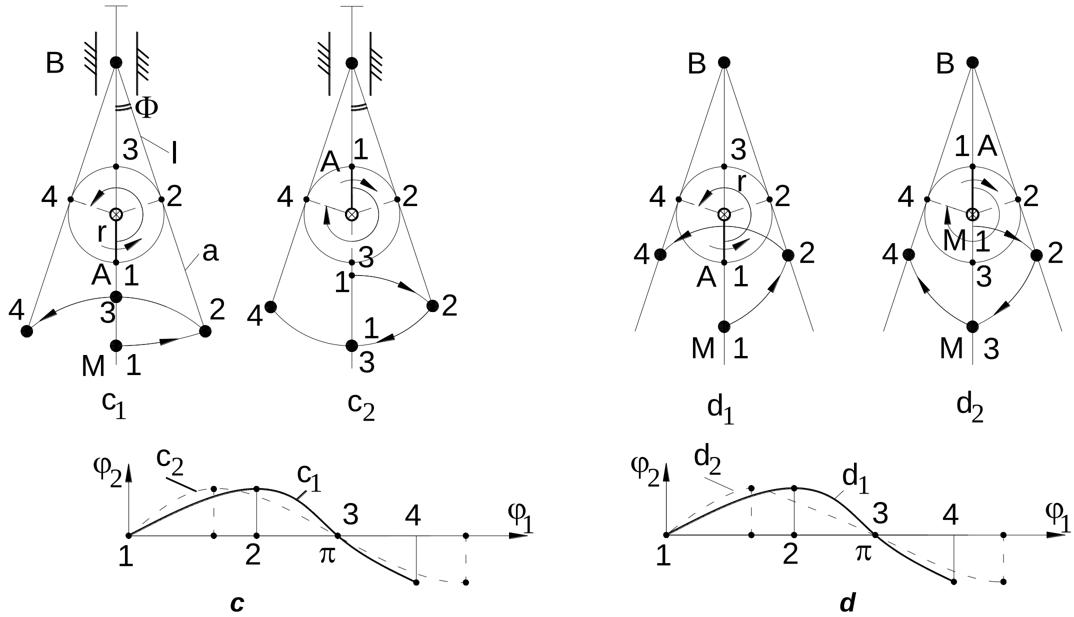


Figure 6. The functionality of single counter mechanisms for integral steering.

In the diagram $\varphi_3(\varphi_1)$, the line corresponds to the positioning in b_1, and the dotted line to the positioning in b_2. The race φ_3 (or s_3) of this mechanism, depends on two parameters *r* and *b*, but also on the length *l* of the lever.

Note that the complete race $\varphi_1 = 270° \pm \Phi$ is obtained at the complete rotation of the steering wheel, which is usually 2 revolutions (i.e. $\Phi_v = 720°$), therefore the front/rear mediation is imposed through gear with proper ratio (see fig.4).

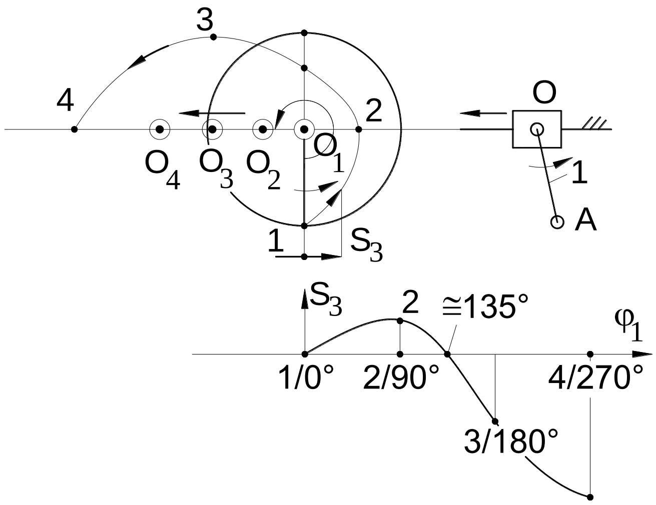
The RRRT guiding mechanism from figure 5,c, having the characteristic point M on the connecting rod, as in figure 6,c, has a similar functionality as the previous one, the handle OA being arranged in the initial position along the guide. The displacement S_2 ($S_2 = (l + a)\sin\varphi_2, \varphi_2(\varphi_1)$) is accompanied by a significant displacement on the direction of the guide, which can be functionally disturbing. Besides the two geometric parameters <u>*r*</u> and <u>*l*</u>, the shape of the function $S_2(\varphi_1)$ depends also on the size <u>*a*</u> on the extension rod.

Similarly to RRTR mechanism in figure 5,a, with the layout, functionality and diagram from figure 6,d, shows the same characteristic position, i.e. areas 1-2, 2-3, 3-4;an exaggerated displacement of the characteristic point M on the direction of base OB, is observed.

The main shortcomings of these mechanisms for integral steering are:

a. Makes races with identical values for steering in the direction tothe front wheels, respectively in the opposite direction, having negative effects on themaneuverability
b. The first part of the race, that of the steering to the direction of the front wheels, is done on a rotation angle of the handle ($\approx 180°$),much too high compared to the angle of steering in opposite direction, also with negative consequences on the maneuverability.

These two drawbacks can be counteracted by moving the center of the handle simultaneously with its rotation, the mechanismbecoming a mechanism with two degrees of freedom, thus, with two driving elements (Fig. 7). For example, essential changes of function $S_3(\varphi_1)$are observed for the mechanism in Figure 5,a/6,a, this way the requirements for integral steering can be achieved.



a.

Figure 7. RRTT mechanism with two driving elements.

3. CONCLUSIONS

Integral steering is defined by the possibility for the rear wheels to be steered in the same direction to thefront wheels (for good stability), as well as in the opposite direction (for good maneuverability).

Integral steering made by purely mechanical structures,requires a special steering box for the rear wheel axle.

Simplearticulated mechanisms with one contour, for achieving symmetry in the left/right steering, should be placed initially (when going straight) with the handle along the base of the mechanism.

Simple articulated mechanisms can achieve the shape of the integral steering function, but its basic requirements are only partially met.

Driving simplearticulated mechanisms by an extra crosshead slipper, namely,mechanisms with two degrees of freedom, a solution found to be fully satisfying the requirements of integral steering.

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References:

1. **Alexandru, P., Alexandru, C.** Mechanisms for the integral steering. 12th EAEC – European Automotive congress, pg. 99, Bratislava, 2009
2. **Berkezeld, V., Seifort, G.** Four wheel steering-handling and disturbance compensation on surface with various friction coditions. SAE paper. no. 925051.
3. **Gatier, L.** Rear steering control device from automotive vehicle with four-wheel steering. United State Patent nr. 4.993.730.
4. **Lupo, G.**Mecanical steering device for rear wheels. United State Patent. no. 4.953.881.
5. **Sano, S.** Vehicular steering system. United State Patent. no. 4.522.416.
6. **Verschoore, R.** Steering geometry errors induced by breaking. SAE Paper no. 865124