Lateral tilting in road vehicles - a review

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Abstract: This paper considers various examples of lateral tilting of road vehicles when cornering. Narrow tilting three wheeled vehicles are considered. Four wheeled tilting small road vehicles, passenger cars with active anti-roll bars and cars with active tilting when moving in a turn are presented. The advantages and disadvantages are discussed.

Keywords: LATERAL TILTING VEHICLES, ACTIVE TILTING, SMALL ROAD VEHICLES, TURN

1. Introduction

When the vehicles move in a bend, a centrifugal force is created, which leads to reduction the comfort of the passengers and the stability of the vehicle. Tilting in land vehicles is being used for the first time in trains. This improves passenger comfort and increases cornering speed. In road vehicles, the principle of tilting is introduced later - in three-wheeled and four-wheeled narrow vehicles, and recently is discuss the use in normally wide passenger cars. The paper will discuss some examples of the applications discussed above and discuss their advantages and disadvantages.

2. Narrow Tilting Three Wheeled Vehicles

Three wheeled vehicles or tri-cycles have better static stability than two-wheelers (motorcycles and mopeds), but poorer dynamic stability when cornering. This is due to the fact that they are usually narrow-gauge and have a relatively high center of gravity. To improve stability, three wheeled vehicles can be provided with a tilting system [1]. Tilting can be done by the driver as in motorcycles or automatically.

Fig. 1 Toyota i-Road [https://www.autocar.co.uk].

Fig. 2 Carver One [https://insideevs.com].

In Fig. 1 is shown a three wheeled vehicle with two front and one rear wheel, and the vehicle shown in Fig. 2 has two rear and one front wheel.

The advantage of the first option is that there is no need to use a differential. In addition, the driver has visibility for the gauge, as the vehicle is wider at the front. While the second option should use a differential for the drive wheels, but at the expense of simplifying the steering mechanism, which is of the motorcycle type.

Recently, there has been a trend to apply the first scheme to mopeds and motorcycles (see Fig. 3 and Fig. 4). This improves their static stability and stability at low speeds. The handling is also improved, especially in poor road conditions and low friction or uneven terrain.

Fig. 3 Piaggio MP3 Sport [https://www.piaggio.com].

Fig. 4 Yamaha NIKEN GT [https://www.yamahamotorsports.com].

Because the front wheels are not wider than the handlebars they are still classified as a motorcycle not tri-cycles [2].

3. Four Wheeled Tilting Small Road Vehicles

These vehicles belong to the group of small city cars. Especially popular in major European cities with high traffic. They are above 50cc and speed not exceeding 45 km/h, and a weight of no more than 550 kg. They can drive with a B1 driver's license from persons over 17 years of age. They have small dimensions and do not require much parking space. The disadvantage is their lower lateral stability due to the narrow track and high center of gravity. To improve cornering stability, some manufacturers offer tilting vehicles of this type. There are also those with electric drive (Fig. 5).

Fig. 5 Nissan Land Glider [https://newatlas.com].
This scheme is also available for all-terrain vehicles (ATVs). In this way, both their cornering and lateral slope stability and their passability when driving on uneven terrain are improved (Fig. 6).

Fig. 6 Self-balancing ATV [http://www.carver-technology.nl].

4. Passenger Cars With Active Anti-Roll Bars and Tilting Cars

In full-size passenger cars of a higher class, active lateral stabilizers are now common, which counteract the centrifugal force and reduce or eliminate the body tilt it causes (Fig. 7).

Fig. 7 BMW Dynamic Drive [3].

Active anti-roll technology is increasingly commonplace, mostly using active anti-roll bars that torque themselves up with hydraulics or electric motors to resist lateral forces, softening off again for the improving of comfort when the car is back in a straight line.

Mercedes’ curve tilting function takes this process to the next level and instead anti-roll bars, they apply actively raise the suspension spring platforms on the outside of the turn and lower them on the inside, creating an effect resembling motorcycle driving [https://www.carmagazine.co.uk]. The curve tilting function can be selected using the three-position ABC switch, and is active in a speed range of 15 to 180 km/h in “Curve” mode. Further selection options include “Comfort” (Magic Body Control with Road Surface Scan) and “Sport” [https://media.daimler.com]. Integrated closely with the Active Body Control (ABC) and Road Surface Scan functions of Magic Body Control, the new feature uses suspension struts which are equipped with hydraulic cylinders that can make the car automatically incline in a fraction of a second and to an angle of up to 2.5 degrees in curves [4]. It can be seen in Fig. 8.

Fig. 8 Mercedes-Benz S-Class Coupe, Active Body Control, curve tilting function [https://media.daimler.com].

The four suspension struts are equipped with hydraulic cylinders, in order to adjust the force in each strut individually. The control unit receives information on the current driving situation from various acceleration sensors, level sensors on the control arms and driving speed. The system then calculates the control signals for the servo-hydraulic valves on the front and rear axle by means of the pressure sensors in the spring struts to ensure suitable proportioning of the oil flows [https://media.daimler.com].

5. Conclusions

The shown technologies are for tilting the chassis of the vehicles. Narrow tilting tricycles and quadricycles can achieve greater tilt angles than passenger cars. In order to achieve a greater reduction in lateral acceleration, additional seat tilting should be applied to them or only the seats should be tilted on their own [5]. However, this is associated with other inconveniences, such as additional mechatronic systems located in the car body, lack of sufficient space for tilting - especially in the rear seats, problems with perceptions and feedback from the driver on the allowable speed in corners and so on.

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References