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Vehicle Dynamics:

BMXJDE3MNE

Ackermann condition of turning

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1. Introduction

The Ackermann-principle is based on solving the geometry problem when a four-wheeled vehicle is on a curved track. The angles of the two front wheels in a turn are 90 degrees(tangent) relative to an imaginary line that goes through the common centre point of the turning cycle which you can see on *figure 1.1 and figure 1.2*. This first kind of steering is called ‘Turntable Steering’ This means that the wheels from the inside and outside have trace circles with a different radius and both front wheels have the same pivot point. Such axles occur with trailers for trucks and tractors and with carriages and carts The centre point of these circles is in line with both axles, this is not the case for example with fork-lift truck. Here the wheels are turning on the backside of the vehicle.

Figure 1.1 : Turning old carriage

The problem with this kind of steering is that the wheels easily slip or worse, the car could fall over. The vehicle is more exposed to the centripetal force (less friction). The flexibility and manoeuvrability with this kind of steering was almost impossible at high speeds. Tight corners could be taken by low speed and with adjusting the wheelbase to longer seizes.

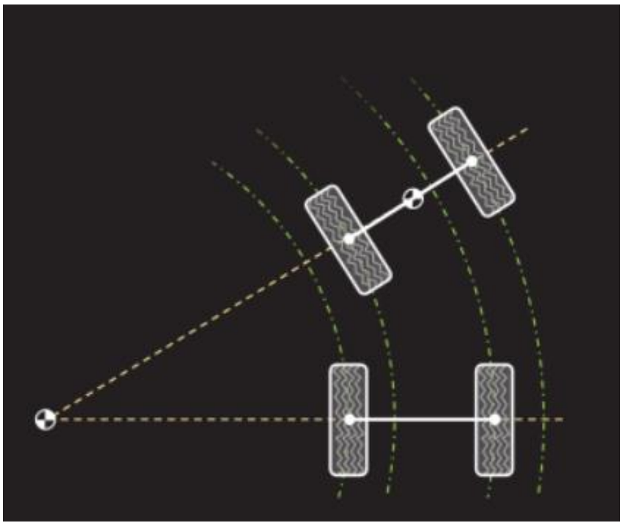

Figure 1.2:Trace circles with different radii

Because of the problem with slipping Georg Lankensperger (1817), who was a German carriage builder, made arrangements in the steering linkage of the car this principle was patented by his representative Rudolph Ackermann. This steering mechanism is still used in many apllications and is known as the Ackermann steering geometry. This steering technique has the best stability in a turn at high speed which is also known as Parallel steering

2. Sideslip

The biggest problem with this issue is the sideslip. The sideslip occurs where executing a turn. It is the amount of displacement in the cross car plane (parallel to the stationary state of the weel). For measering the sideslip you have to take in account the rotation of the tires (dependent of steering technique), turning speed of the wheels and the friction between the wheel-surface from the road (depends on the material).
The slip angle (rotation) can be measured by the force in line with the tire v_x and the one perpendicular on the wheel v_y:

$$\alpha = \tan^{-1}\left(\frac{v_y}{|v_x|}\right) \tag{1}$$

The main aim is to get the slip angle as small as possible(*figure 2.1*).

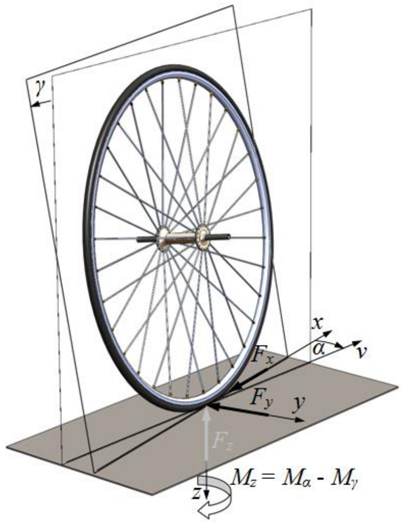

Figure 2.1 : Slip angle caused by sideslip

3. Solutions

3.1. Simple steering (old/carriages)

This technique gives each wheel an pivot.The type of steering solves most of the problems but the side-slip issue is still a problem. Both wheels have the same angle relative to the horizontal line made by the rear axle. By doing this you can see on *Figure 3.1* that each front wheel has a different rotation centre.

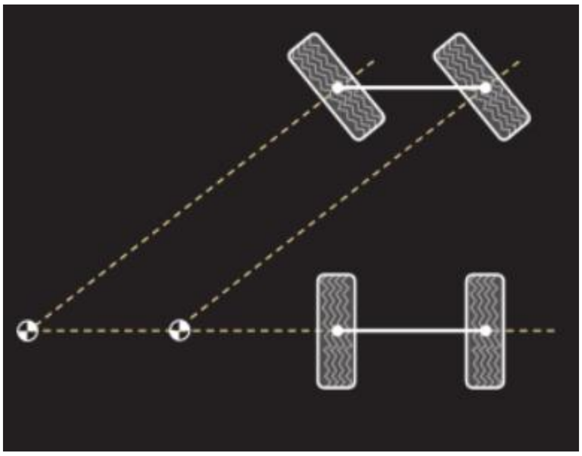

Figure 3.1: Simple steering

With this type one of the front wheels will experience sideslip. This is big disadvantage, the traction power to overcome the addidional friction is to large compared to the turntable steering. Even independent from the speed the car would easily drift sideways if the road is for example a gravel driveway.

3.2. Ideal/Ackermann solution

3.2.1. Ideal (differential) solution

The ideal solution is that each wheel turns independently (differential) and is mostly used by offroad vehicles like the ones from John Deere (company for agricultural and tractor machinery).

The design of this is made so the angle of the front wheel on the outside is smaller then the one on the inside. This method is used to have a common center point for both tires. To calculate both agles we can simply use the geometry without including the external forces. (2) is the equation for the angle of the inside wheel relative to vertical (parallel with tires on the back) and (3) is for calculating the angle of the inside wheel.

$$\alpha_{inside} = \tan^{-1}\left(\frac{L}{R-\frac{T}{2}}\right) \quad (2)$$

$$\alpha_{outside} = \tan^{-1}\left(\frac{L}{R+\frac{T}{2}}\right) \quad (3)$$

$$\alpha_i = \tan^{-1}\left(\frac{\left(R+\frac{T}{2}\right)\tan\alpha_0}{R-\frac{T}{2}}\right) \quad (4)$$

- *T*: the distance between the 2 fix points of the wheels from one axle.
- *L*: distance between the 2 centerpoint from the axles.
- *R*: Distance between center point of turning cycle and the centerline from the vehicle

On *figure 3.2* you can see the charateristics of the fronth wheels compared to the simple steering ($\alpha_i = \alpha_0$). You can see how tighter the corners are for turning how bigger the difference becomes between bot angels of the front wheels. Which is normal if you look at (4) R will be lower so the angle on the inside will be higher if you fill in (3) and (4). The lower you will go the greater the difference.

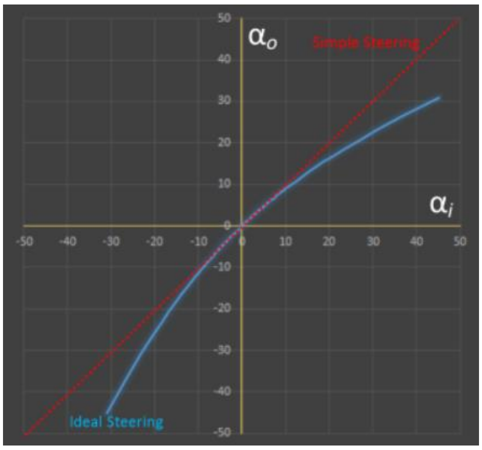

Figure 3.2: ideal compared to simple steering

De aim of ackermann steering is getting as close as possible to this characteristics.

3.2.2. Ackermann steering geometry (mechanism)

He was the one who came up with the idea to make arrangements in the steering linkage of the car and is bases on the ideal solution shown on
The ackermann mechanisme is an idea of making arrangements in the steering linkage of the car. It only apllies to one axle, the front axle. Both side are equipped with stubs which is shown on *figure 3.3*. In normal position (straight) the line draw through both stubs has to cross in center point of the rear axle. This make some kind of rack and pinion system for steering cause of the connection betwoon both pivot points.

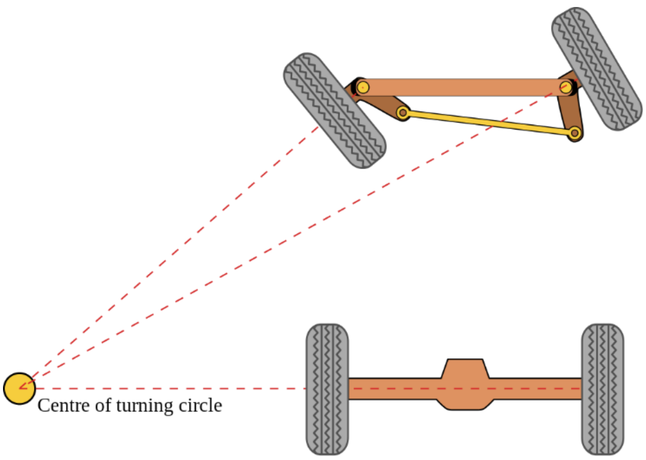

Figure 3.3:Ideal solution Ackermann-principle

The most important advandtage is that all wheels have less chance from slipping sideways in a turn. Each wheel has its own pivot which are joined by a rigid bar called the tie rod. Not all cars use this purely because there is still a big chance of falling in sharp turns. Racing carse use the reverse geometry to compensate the large differences from the slip angles from the wheels on the inside and outside. It compensates the heating of the tires at high-speed turning but at low speed movements it compromises the low-speed manoeuvres.

On *Figure 3.4* you can see with this kind of linkage geometry we go really close to the ideal solution. Its even beter at really sharp turns in comparrison to the ideal one, unfortunatly this is not really an advantage because the probability of capsizing with the vehicle is higher in this case thats why normal cars don't use the pure steering. They optimalise the mechanisme so the turning of the car would be smoother and the maintainance of the tires would be better.

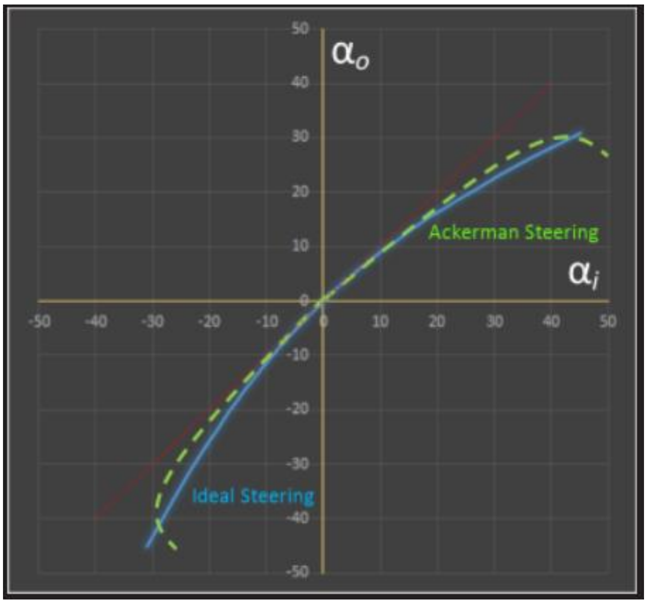

Figure 3.4: Comparison ideal an ackermann solution

4. Sources

[1]*Slip angle*, on 6/12/2019 Retrieved from https://en.wikipedia.org/wiki/Slip_angle

[2]*Ackerman steering*, on 6/12/2019 Retrieved from http://datagenetics.com/blog/december12016/index.html

[3]*Ackermann-principle*, on 8/12/2019 Retrieved from https://nl.wikipedia.org/wiki/Ackermann-principe