Vogel Fachbuch

Wheel Alignment

VOGEL

Thomas Vauderwange

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Dipl.-Ing. Thomas Vauderwange

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About the author:

Thomas Vauderwange, born in 1968, holding both an MSc in aerospace engineering and an MBA, has been working many years in Product Management and Development of innovative wheel alignment systems. He has been a key contributor in development and the way to market of the world's only touchless wheel aligner, the CURA R2000.

Additional informations:
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Preface

Imagine you had a car workshop. In this workshop, your technicians perform oil changes on cars. Quality-aware as you are, you want to have a reliable idea of what your people do. So, you ask every customer that is about to drive away after the oil change whether you may take a short look at what was done, and double check. The customers are co-operative. After checking 10 cars, you find half of them where the oil change was not done, or was done incorrectly.
Your technicians take care of it, you inspect the five cars once more – and still find two, where the oil change was not completed correctly.
More than likely you would have a job opening in oil change.
But look what happens in so many workshops when it comes to wheel alignment. A lot of effort is spent to prepare the car, the technician measures to the best of his and the available equipment's abilities. He finds values that are out of tolerance. Adjustments are made so that the values get in the green. The technician takes the vehicle on a test drive and a crooked steering wheel is glaring proof that something went seriously wrong measuring this car. All the time and effort needs to be duplicated. Even worse, if the errors made happen to be symmetrical, the error is not even noticed, and the customer returns some 5000 km later to present tires that are worn out on one side.
More often than not, the steering wheel is still crooked after several tries.
How unrealistic is it really to compare this to oil changes that were not made? The fact that it takes either complete incompetence, or negligence to mess up an oil change, is obvious. The technician, however, is dependent on the wheel alignment system utilized. From an economic standpoint, in both cases, you're wasting precious labour, and play hazard with your customer's patience.
It is the goal of the ‚Wheel Alignment Academy' to get this part of the profession away from the dark corner of mystery inside the workshop. It has to be a regularly performed workshop service that each involved party enjoys – including the fact that there is serious money to be made with it.
Sincere thanks are in order to Marty Crane, life-long wheel alignment Pro, who took the challenge to rework the author's first attempt for an English translation.

Thomas Vauderwange

Even beautiful Old Timers require wheel alignment from time to time

Content

Part 1

Basics and Procedures – Four Steps to a Straight Steering Wheel

1 Basic measurement of a dynamic chassis: Toe, camber, and all that comes after

This section is designed to lay the foundation for the course. Sometimes even toe is misunderstood! On the other hand, toe is the No.1 parameter to be adjusted. We all know that if the individual toe angles are not adjusted symmetrically even a customer with poor eyesight will know immediately that the steering wheel is not straight.

Imagine an old fashioned hand cart, one axle with two wheels. As we want to start the basics from scratch, let's have it with the wheels aligned real straight, both lateral and vertical. To the non-initiated spectator, this will look like the perfect chassis, everything straight!

Those of you that began your mechanical engineering experience with LEGO bricks will remember, that there is no natural tendency to mount wheels other than in a perfectly vertical and straight way.

If you are new to alignment please understand that this situation is anything but ideal for the real world. Still, a good example.

Let's see what happens if we pull this cart along a straight street. Logical thing, you will say, it will run after me with the holding bar perfectly in line with street (Fig. 1.1).

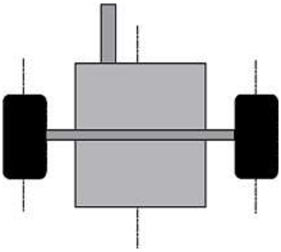


Fig.1.1
Hand cart with straight wheels

In the second step, we assume the quite luxurious case of a cart with adjustable toe. We adjust both wheels in such a way, that both of these are clearly pointing to the left (Fig. 1.2).

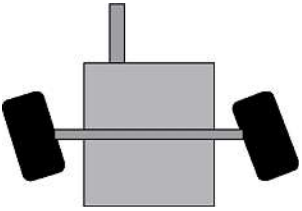


Fig.1.2
Hand cart with wheels to the left

Please try to figure out what will happen, when you pull that cart along a straight line.

The result will roughly look like that (Fig. 1.3):

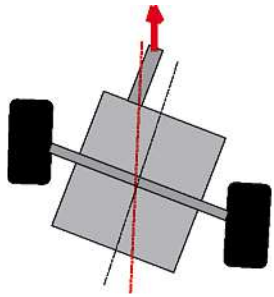


Fig. 1.3
Cart with wheels adjusted to the left, rolling straight. Red: Thrust line

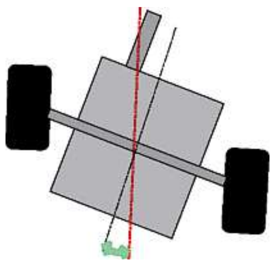


Fig. 1.4
The Thrust Angle

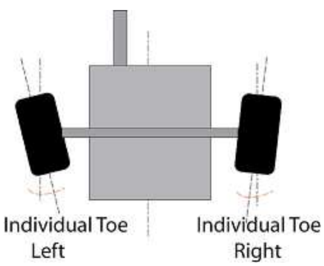


Fig. 1.5
Individual Toe Angles

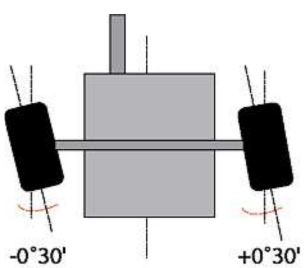


Fig. 1.6
Individual toes, measured

Time for a few definitions:

Symmetry line: (grey) the line formed by cutting the car exactly in half. In case of the hand cart, this line is parallel to the holding bar.

Thrust line: (red) the line formed based on the angle of the two wheels, along which the vehicle will roll in a straight line. In the example given in fig. 1.3 (red), this line is clearly biased to the left of the symmetry line.

! ***The vehicle will adjust itself to that line, then it will perfectly stay there. There will be no tendency to pull or drive a curve! The only thing is, the cart will constantly «look to the right» while rolling straight.***

Once a car is built and adjusted in a fully symmetrical way, the symmetry line and the thrust line are identical.

Thrust angle: We call the angle that is formed between the symmetry line and the thrust line the «Thrust Angle». It is shown in green in Fig. 1.4. Under ideal circumstances, it is zero.

Up to this example, we have always assumed that both wheels are somehow parallel. Only in the rarest of cases will this situation occur. In order to determine whether or not a wheel is in line to the chassis, we need a new angle. The angle formed between the symmetry line and one wheel (Fig. 1.5).

Individual toe rear left/right: The angle between the symmetry line and a lateral line through the wheel.

These angles are usually measured in degrees and minutes, whereas one degree is composed of 60 minutes. Half a degree equals 30 minutes, noted like this: +0°30′.

In Fig. 1.2 we considered the case that both wheels were misaligned an equal amount to the same side. By the way, this is exactly the case of oppositely equal individual toe values, as individual toe is by definition positive when pointing in at the front of the wheel (right wheel) and negative when pointing out (left wheel).

Given the additional information that the thrust angle is defined clockwise positive, we can easily determine the thrust angle value of –0°30'. The thrust line being parallel to the two wheels (Fig. 1.7).

Opposed to that, we will now adjust the left wheel in by 30' (Fig. 1.8).

What will happen if this car tries to drive straight? The left wheel would like to turn the whole chassis to the left, so that it can roll straightly on the street. Nice plan, only the right wheel would like to do exactly the opposite!

Automatically, they will meet half way. As both wheels are trying to turn with the same strength, the chassis will stay perfectly in line with the symmetry line on the straight way ahead. In other words, the thrust angle is exactly zero (Fig. 1.9).

In real life, you will find whatever possible combination of toe values right and left, and normally they will not do us the favour of being equal.

To illustrate that, we return to the situation as shown in Fig. 1.10 and measure the toes:

Again, we want to know what will happen once that cart rolls straight.

Again, both sides compete as to in what direction the cart will look while driving straight. The left side would like to turn the cart by 30' (read that as «thirty minutes») to the …

Quiz 1

a) left

b) right

… while the right side would prefer to turn the cart by an angle of …

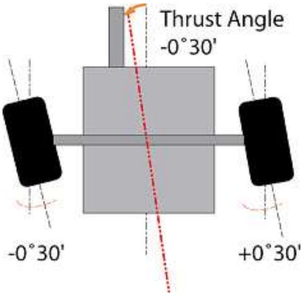


Fig.1.7
Negative thrust angle, wheels parallel

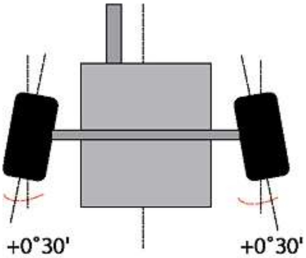


Fig.1.8
Symmetrical, positive toe

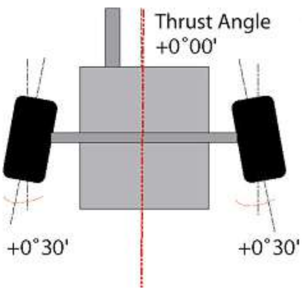


Fig.1.9
Thrust angle zero with positive toes

Tip

The solutions to all of the small quizes you receive in our online service **InfoClick**.

The informations about your personally code you can find at the beginning of this book.

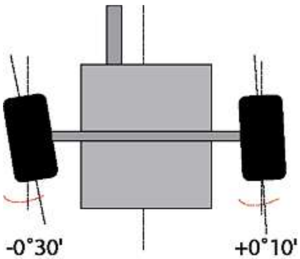


Fig. 1.10
Different toe values right/left

Quiz 2

a) 5′

b) 10′

c) 15′

d) 20′

e) 30′

It would prefer to turn the cart to the …

Quiz 3

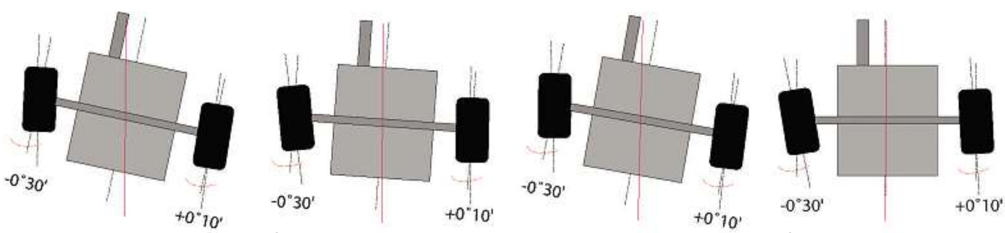
a) left.

b) right.

If you feel uncertain with the answer, check each wheel individually using the examples given before. Exactly as shown before, neither side gets exactly what it wants. Try by yourself to develop the solution. We want to know what happens once we start pulling the cart along a straight line. Please decide what it will look like.

Quiz 4

Which image shows the correct solution?



a) b) c) d)

For the correct answer, you have to rotate the cart in such a way, that both wheels are the same distance away from their ideal, natural run-straight position. In this case, we will soon arrive to a first statement that the cart will have to be turned to the ***right***, as both wheels agree to being misadjusted to the ***left***. The left wheel would like to turn the cart by 30′, the right one would prefer turning 10′ in the same direction. As a result, the cart will be rotated by …

Quiz 5

a) 5′

b) 10′

c) 15′

d) 20′

e) 30′

… to the right, and then stay in that direction while running straight. One could say that the cart has a thrust angle of ...

Quiz 6

a) +10′.

b) +20′.

c) +15′.

d) –20′.

e) –30′.

On the basis of the cart being correctly adjusted to roll straight, we will now consider the total toe, that can be either promoter of stability, or cause of extensive wear & tear. The total toe can be described as the sum of how much each wheel is away from its perfect roll-straight position, once the car is adjusted to its drive-straight heading. In our first, simple examples with the two wheels parallel, total toe was zero. In the last example, we had a thrust angle of –20′, from which the left toe is way by 10′. Now think twice: The right toe is away from this thrust line by …

Quiz 7

a) 0′

b) 10′

c) +20′

The total toe yields as the sum of these two differences to the thrust line, whereas the sign of that value will tell whether the two wheels will form an angle open to the front (–), or open to the rear like a snow plough (+), looking along the drive-straight direction.

In this case, the total toe is …

Quiz 8

a) 0′.

b) –10′.

c) +20′.

d) –20′.

Only to foster easier understanding, we derived total toe using the thrust line. In reality you could just as well use the two toe values in whatever correct definition, and simply add them up. In our example, one could use the two values that are measured against the symmetry axis: Left –30′, right +10′, yielding;

total toe = toe left + toe right = –30′ + 10′ = –20′

Total toe: The sum of two individual toe values. The angle is negative when open to the front and positive when open to the rear.

Seeing the idea, that each wheel would ideally prefer to run straight in its natural straight direction, one can now imagine how it creates stability when having some total toe on an axle. Both wheels will nearly 'bite' the road trying to push inwards.

Up to now, we only spoke about a one-axle hand cart, seemingly off-topic. The good news: In most cases, only the rear axle is more or less fixed. The front axle flex into the drive-straight position, unless the driver applies real force. This means that the example of the hand cart axle applies primarily to the rear axle of a car.

One can start with the example of the one-axle hand cart (including individual and total toe, as well as the thrust angle), and then extend the cart somewhat to the front. At the front, we add a steerable axle instead of the pulling bar. On this axle, the position of the two wheels towards each other is fixed (and this is the total toe). Otherwise, both of them can move freely as they see fit (Fig. 1.11).

It is not by oversight, but with a good reason, that the front wheels are not measured against the symmetry line. Instead, their angle is being measured against the thrust line.

Individual toe front left/right: The angle between the thrust line of the car and the vertical on the turning axle in the left / right front wheel.

To remind you: The thrust line is …

Quiz 9

a) the angle between the total toes.

b) the angle between symmetry line and bisecting line in between the two rear wheels.

c) the line along which a car drives straight.

When driving straight, something special happens to the two front toe values. They will be …

Quiz 10

a) both zero.

b) equal.

c) both negative.

All of a sudden, it gets clear why the two front toes are measured in reference to the thrust line. When adjusting toe with the steering wheel put straight, all you have to do is to make sure that the right toe is exactly the same as the left.

We cannot repeat this often enough: As much as misadjusted toe values can cause «crabbing» of the car (it looks constantly to one side while driving straight), or even bad wear & tear. There is one thing it can not cause, pulling in one direction.

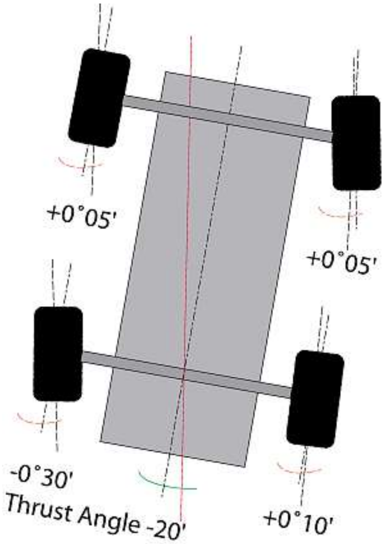


Fig.1.11
The hand cart upgraded with a steerable front axle