ANALYSIS AND SELECTION OF LIGHT VEHICLES STEERING SYSTEMS.

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Abstract- Light vehicles are gaining ground in personal transportation, they are made up of simple systems due to their lightness. The steering systems for this kind of vehicles implement the steering wheel or handle wheel in center position. These systems are generally used in Go-Karts, QuadBikes (four-wheel bikes), lawn mowers, etc. This paper provides a method to select the best configuration of mechanical steering systems for light vehicles. A small error is obtained by this method due to the favorable proximity to the theoretical steering system.

Resumen- Los vehículos ligeros están ganando terreno en el trasporte personal, se conforman de sistemas sencillos debido a su ligereza. Los sistemas de dirección para este tipo de vehículos implementan un manubrio o volante al centro. Se usan generalmente en Go-Karts, QuadBikes (bicicletas de cuatro ruedas), podadoras y cuatrimotos. En este trabajo se proporciona un método para seleccionar la mejor configuración de un sistema de dirección mecánico de barras para vehículos ligeros. No es grande el error que se produce mediante este método, debido a la pequeña diferencia que existe en cuanto al sistema teórico.

Key words: QuadBike, Ackerman geometry.

Nomenclature.

d- track width.
l- wheel base.
R i, i = 1, 2, 3, 4 – inertial coordinate vectors.
r i, i = 1, 2, 3 – local coordinate vectors.
R φ i, i = 1, 2, 3 – rotation matrix.
x i, i = 1, 2, 3 – dimensions of levers 1, 2, 3.
x 4 – horizontal distance between steering axle point and steering knuckle pivot.
y 4 – vertical distance between steering axle point and steering knuckle pivot.
α - initial angle of lever 1.
β - initial angle of lever 2
γ - initial angle of lever 3.
θ i - inner wheel angle.
θ o - outer wheel angle.
θ h - handle wheel angle.
ϕ i, i = 2, 3 – angles of the levers 2, 3 obtained due to the simulation.

I. INTRODUCTION.

In present days, there are several problems in the personal transportation. The global warming due to the pollution produced by the base-oil fuels and the lack of space in Mega Cities are some of these problems. The light vehicles are one solution to these problems, they can transport people with a little energy due to their lightness. Currently, these kind of light vehicles are made with ultralight materials like carbon and kevlar fibers. As these vehicles do not consume high energy, it is commonly to see these vehicles powered with electric traction systems. The principal steering system purpose is give to the driver the directional vehicle’s control. The steering system goes since the steering wheel or handle wheel to the steering wheels through levers and ball joints.

This paper presents the steering system development for the light vehicle shown in Figure 1. There are several softwares specialized in the development of mechanisms, like ADAMS, where advanced kinematic analysis is used to develop mechanisms [1], making it difficult to develop complete steering systems. However, this paper presents a fast and easy way to develop steering systems for light vehicles using Ackerman geometry and Mathematica 7.0.

Figure 1. Carbon fiber QuadBike.
II. ACKERMAN GEOMETRY.

The steering system was designed under the Ackerman geometry. When a four-wheeled vehicle is turning in a curve, Figura 2, the front wheels are not parallel. The Ackerman geometry gives the relationship between the two front steering wheels [2], Equation 1.

\[
\cot \theta_o - \cot \theta_l = \frac{d}{l} \quad (1)
\]

Then, it is possible to obtain one equation for each wheel in function of the steering wheel [3], Equations 2 and 3.

\[
\cot \theta_o = \cot \theta_c + \frac{d}{2l} \quad (2)
\]

\[
\cot \theta_l = \cot \theta_c - \frac{d}{2l} \quad (3)
\]

Table 1 shows the values used for the QuadBike.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Dimension (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>l</td>
<td>1200</td>
</tr>
<tr>
<td>d</td>
<td>930</td>
</tr>
</tbody>
</table>

With equations 2 and 3, it is possible to know the behavior of the steering system. It was done a graphic showing this behavior, Figure 4.

Where the black line is the inner wheel, the red one is the outer wheel and the yellow one is the difference between both lines.

III. THE STEERING SYSTEM DEVELOPMENT.

In order to start the steering system development, it was necessary to know the dimensions of the QuadBike frame and the dimensions given by the suspension system. The dimensions are showed in the Figure 5.
It is now possible to make some configurations of levers trying to do the best steering system configuration. The best steering system configuration is the steering system which its behavior is the closest to the theoretical QuadBike Ackerman geometry. This process was made in four steps:

Step 1: Some levers configurations were drawn with SolidWorks (or any CAD) in order to obtain the dimensions of each lever and their initial angles, Figure 6.

Step 2: It was made one simulation for each configuration in Mathematica 7.0.

With the dimensions obtained in the Step 1, several levers systems were built in Mathematica and the equations and the simulations were prepared for each levers system.

The analysis which describes the mechanisms is shown in Figure 7.

The position vector equation is written as:

\[ R1 + R2 - R3 - R4 = 0 \quad (4) \]

Where:

\[
\begin{align*}
R1 &= [R_{\phi_1} x_1] \\
R2 &= [R_{\phi_2} x_2] \\
R3 &= [R_{\phi_3} x_3] \\
R4 &= [x_4, y_4] 
\end{align*}
\]

where:

\[
[R_{\phi_i}] = [\cos \phi_i \quad -\sin \phi_i \quad \sin \phi_i \quad \cos \phi_i]^T \quad i = 1, 2, 3
\]

\[
\begin{align*}
r1 &= [x1, 0]^T \\
r2 &= [x2, 0]^T \\
r3 &= [x3, 0]^T
\end{align*}
\]

It is made the same analysis for the other mechanism side due to the same dimensions used in both sides. In the Figures 8 and 9 it is observed two configurations of levers made in Mathematica.

Step 3: The angles of the wheels (inner and outer) from each simulation were exported to some Excel file.

In Mathematica it is possible to create Excel files. In these files, the angles for each wheel (inner and
outer) versus the steering handle wheel angle were obtained in order to have the behavior of each lever configuration and compare it with the theoretical QuadBike Ackerman geometry.

Step 4: The data of each lever configuration was put into the graphic of the theoretical QuadBike Ackerman geometry and the best configuration was selected.

Several configurations were done, but only the most important configuration is shown into the graphic, Figure 10. As it is known, the QuadBike has the center of mass high relatively with its dimensions when the driver is on it, so it is necessary to select a special combine of suspension system and steering system due to try to reduce the amount of body roll in a turn. So, to have the QuadBike in understeer configuration was needed. Understeer is the tendency for a vehicle to continue to increase the diameter of the turning circle as vehicle speed increases while holding a given steering wheel position. Understeer provides the average driver with a large safety margin when entering a turn because the vehicle has a slow response [4]. The steering system chosen was the closest to the theoretical QuadBike Ackerman geometry. This system drew the blue, brown and gray lines. A slow response was achieved with the steering system chosen. The mechanical configuration for this system is shown in Figure 11.

The dimensions of the steering system chosen are shown in Table 2.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Dimension</th>
</tr>
</thead>
<tbody>
<tr>
<td>x1</td>
<td>90mm</td>
</tr>
<tr>
<td>α</td>
<td>10°</td>
</tr>
<tr>
<td>x2</td>
<td>376mm</td>
</tr>
<tr>
<td>β</td>
<td>15.6°</td>
</tr>
<tr>
<td>x3</td>
<td>120mm</td>
</tr>
<tr>
<td>γ</td>
<td>13°</td>
</tr>
<tr>
<td>x4</td>
<td>405mm</td>
</tr>
<tr>
<td>y4</td>
<td>130mm</td>
</tr>
</tbody>
</table>

The diagram of the steering system chosen is shown in Figure 12.

Connecting the levers with themselves and the tire trunk is the task of the bearing points. This task is a very important one because this connection must be very resistant, exact and reliable. Rod ends are proven as well in automotive application and are further easier to handle. The joint socket is manufactures accurately so that the slackness can be wholly excluded. Furthermore rod ends are available in all different sizes, in many different material combinations and in varied designs and models. So, consequently rod ends were used for the QuadBike, Figure 13. The choice came down on parts from FLUROGelenklager GmbH wich is a high quality joint bearings manufacturer.

In order to achieve a very lightweight steering system, the decision was made to use carbon tubes for constructing the steering system levers. With carbon tubes it was possible to guarantee the required...
resistance and stiffness together with a minimum gain in weight. The used carbon tubes, Figure 14, were manufactured with ten unidirectional and two 45 degree top layers for carrying all applied forces in different load cases.

![Figure 14. Carbon fiber tubes with rod ends.](image)

The Figure 15 shows the steering system installed.

![Figure 15. The steering system installed.](image)

IV. CONCLUSIONS.

This paper presents an easy and fast method to develop a mechanical steering system. The system developed in this paper is not exactly as the theoretical QuadBike Ackerman geometry. However, the tires angles drew lines very close to the theoretical Ackerman geometry. The difference between the theoretical and the final real system is minimum, making the system totally useful.

It is recommended to make understeer vehicles when the driver is driving outdoors vehicles in order to provide a large safety margin when the car is entering in a curve.

V. BIBLIOGRAPHY.


