Development of a New Software for Racecar Suspension Kinematics

Andrea Candelpergher, Marco Gadola and David Vetturi
University of Brescia

Reprinted From: Proceedings of the 2002 SAE Motorsports Engineering Conference and Exhibition (P-382)
ABSTRACT

In the racecar design process the definition of suspension type and geometry is an important stage. A good design of the main parameters, in terms of static and dynamic angles in bump and steer, is the basis of a successful racecar quite often.

This paper aims at introducing the development of a new software tool, called MLKrace, that can analyse the suspensions kinematics for a wide range of different layouts.

There are today a lot of commercial tools that analyse or simulate suspension behaviour. In general their application is restricted to the classic double wishbone suspension and in this case the calculation of the kinematics is not so difficult. This layout is used on both ends of the majority of formula and sports race cars but it isn’t the only possible one.

The MLKrace software is instead more suitable to analyse innovative suspension geometries, the mathematics being based on the resolution of the so-called Stewart platform, a method originally devised for parallel robot kinematics. Therefore full multi link or hybrid systems can be designed as easily as a double wishbone. In addition push rod, pull rod or outboard spring systems can be added and the driveshaft required float is computed. Multilink-McPherson hybrid suspensions can be designed as well. The flexibility is the great advantage of this new software.

Apart from the mathematic model, a massive effort was devoted to the design of the Windows interface with the aim of making the designer’s job particularly easy and effective compared to outdated MS-Dos interfaces of most of the existing software. The output is shown in the form of 2D and 3D animations, a large number of predefined diagrams, numeric tables and regression functions.

INTRODUCTION

The suspension design process is an important point in the development of a new car or in the tuning of an existing car.

As a matter of fact tyres can produce forces to generate high lateral and longitudinal acceleration only if they work in the proper way, where this means with a good contact area and angles. These angles are camber and toe.

Figure 2 shows the effect of camber angle in cornering force. A general rule is that negative angles give more lateral force.

But the optimum angle depends on the type of tyre and its application. The designer tries to keep it constant to have the best performance.

In the design phase the suspension is conceived in a static configuration that defines the main parameters of the geometry. On the track, road bumps, load transfer and aerodynamic downforce produce a relative movement of the wheel. It is also important to study the
variation of these parameters when the wheel is moving in bump and steer.

A typical problem is to avoid “bump steer” or the toe change along the bump motion; this is a negative characteristic as it can upset the vehicle behaviour.

Compared to other commercial suspension design software MLKrace is easy to use and complete and results are particularly accurate.

SUSPENSION DESCRIPTION

In the description of a new suspension the designer needs to input a lot of information. MLKrace’s main screen presents various options to define the suspension type and layout. The first parameter to set in the suspension is the layout. There are 5 possibilities:

1. **Multilink**: the most general type of suspension that gives the possibility to have virtual steering axis and a good control of angles.
2. **Bottom multilink - Top wishbone**: a multilink where top arms are connected to form a wishbone.
3. **Top Multilink – Bottom wishbone**: a multilink where bottom arms are connected to form a wishbone.
4. **Double wishbone**: top and bottom arms are connected to form a wishbone.
5. **McPherson**: A strut geometry where the bottom links can be separated or connected to form a wishbone.

The developed software “MLKrace” allows the designer to analyse the suspension system and to modify its characteristics for improvement.

The choice of the suspension type is the first step in suspension design and MLKrace gives the opportunity to analyse different layouts to compare parameters, performance and overall dimensions.

When the main layout is defined the design phase begins where the designer can move links and rods to obtain the best compromise for the specific car and application (road car, sportscar or formula).

MLKrace aims to simplify the design process with the following features:

- Modelling of the most common configurations
- High quality and user-friendly interface
- Fast and accurate calculation
- Graphic representation of the suspension
- Wide selection of displayed results
1. Outboard spring linked to one of the arms or to the upright.
2. Push or pull rod linked to upright or arms, with an additional rocker to give the movement to the spring.

Other forms of the software are dedicated to information about wheel radius, brake balance, static camber and toe to complete the suspension layout.

The mathematic model is based on the resolution of the so-called Stewart platform, a method originally devised for parallel robot kinematics. The platform is a rigid body, with 6 degrees of freedom, linked to the still frame through 6 rigid, hinged links. This system is isostatic but if one of the links is removed the platform has a degree of freedom.

In the suspension system the upright is the rigid body, and this is linked to the car chassis by means of suspension arms. In a multilink suspension there are 4 fixed-length links i.e. the suspension arms, the steering rod and the spring/damper link. These last two links can give two degrees of freedom for steering and bump motion. The steering rod can translate transversally when the rack moves and the damper can change its length. Other types of suspension, like the double wishbone, can be considered as a modification of the multilink layout, connecting two upright points together.
(α, β, γ) and three coordinates (X,Y,Z) describe its position relative to the chassis.

The joint centers on the upright have a “relative” position in the mobile axis system and an “absolute” position in the chassis axis system.

The relative position doesn’t change during the movements and it is defined in the static configuration; the absolute position changes and it is obtained by multiplying the position vector and a rototranslation matrix.

The calculation for the rocker position is another Newton-Rapson solver where the variable is the rocker angle.

**Calculation**

To calculate the correct position of the upright when the spring length changes in bump or when the steering rack moves, a Newton-Rapson solver is employed. This acts on the 6 variables that define the upright position. The solution is viable when each distance between rod ends on upright and chassis is equal to the original link length.

The calculation for the rocker position is another Newton-Rapson solver where the variable is the rocker angle.
RESULTS

The final result is the position of the upright with all the connected points and the rotation of the rocker. With these information is it possible to calculate all the traditional suspension parameters. The most important ones are:

- Camber, caster, kingpin, toe
- Track and wheelbase variation
- Scrub radius and trail
- Relative and absolute roll center height
- Anti-dive or anti-squat effects
- Ackerman angle

A preliminary computation of the steering axis and tyre contact patch center position are required to compute various other parameters. The former can be found by means of a small steering movement to define the real axis of rotation of the upright. The second is the lowest point of the middle circle of the wheel. It is also possible to study a combination of bump and steering.

All the suspension parameters for the required range of positions in bump and steering are calculated and stored in a results matrix.

POST-PROCESSING

For an easier understanding of the behaviour of the suspension, the results are immediately plotted in diagrams as a function of bump travel or steering angle. Numerical results can also be displayed in table form; it is possible to copy them to the windows clipboard or print them for a further analysis or comparison.

A polynomial fitting curve can be overlapped and the coefficients are shown in the table beside the graph. These are important figures for the designer because they can describe the suspension behaviour where it is not possible to take into account the suspension geometry as a whole, in a lap time simulation software for instance.

Comparing different solutions can be quite useful within the process of development. Therefore MLKrace can display the current geometry overlapped on a reference one for each parameter.

Animations of the suspension movement are also available in 2D or 3D for a visual understanding of the movements.

VALIDATION

The software was used to study various existing suspensions and the results for a Formula Renault 2000 racecar have been compared with a multibody model. The comparison showed that creating a suspension with MLKrace is a fairly quick, easy and straightforward task.
Results for all parameters are the same with an error under 1%. This confirms the accuracy of the mathematic process.

CONCLUSION AND FUTURE DEVELOPMENTS

A method for studying racecar suspension kinematics has been described. This is based on an innovative mathematic method and has originated a software - currently under development- conceived as a support to the racecar designer.

Future developments:

- Computation of link forces in a defined load case
- Elasto-Kinematics, with AV suspension mounts
- Anti-roll bar geometry
- ….

REFERENCES


CONTACT

Andrea Candelpergher gained a PhD in Applied Mechanics at the University of Brescia. His particular interests are race car dynamics and simulations.

E-mail: candel@ing.unibs.it