MotionPro – Kinematic Modeling, Simulation and Optimization of a Double-Wishbone Suspension

The dynamic stability of a vehicle, as well as fuel efficiency and tire wear, is directly affected by the kinematic behavior of the suspension mechanism. A great deal of effort is needed to achieve the best possible movement of the wheel camber, caster and toe-in as the suspension responds to a bump in the road. This is particularly complex to achieve in a double-wishbone suspension because there are ten joints that influence the geometry of the system, as well the positions of the centers of the wheel and the steering cylinder. These are known as the “Hard Points” and are defined as coordinates in space, relative to a global reference frame, when the suspension is designed.

The challenge is to define these hard points in order to achieve the desired kinematics for the vehicle. Using Maple and DynaFlexPro, it is very easy to graphically define the topology of the mechanism using blocks and lines, from which the equations that define camber, caster and toe-in are automatically derived in parametric terms (that is, as symbolic variables that have yet to be assigned numerical values).

Once the model has been defined, the engineer can enter the numeric values for the x,y,z coordinates of each hard point. Maple then solves the resulting system of ODEs to produce the camber, caster and toe-in over a given vertical displacement applied to the wheel (in this case, a sine wave of amplitude 100mm to represent a bump and rebound).

These are the results for a given set of hard-point values, defined prior to performing the calculations. Normally, these values are compared with standard curves to ensure that they comply with the desired kinematics for the vehicle. Of course, on a first pass this is very unlikely and the engineer will need to adjust the hard points to give the desired curve, which can be very painstaking and time-consuming.

A more efficient method is to import the standard curves as data sets and use the Global Optimization Toolbox for Maple. Using the imported curves as the objective functions, you can identify which hard points can be moved (very often, there are only a few that can be moved because of other design constraints) and by how much. The Global Optimization toolbox will then find the “best-fit” coordinates that will produce the kinematics closest to the desired curves.

“...the ability to turn these types of calculations around very quickly saves us a lot of time. This in itself is very useful, but the ability to automatically fit the responses to published results is very exciting indeed.”

John McPhee - Chief Scientist, MotionPro Inc

Once you have optimized the model you can then export it to Simulink as an s-Function block using BlockBuilder for Simulink, so you have a very high fidelity component for simulating the vehicle, particularly in real-time for hardware-in-the-loop testing in the lab but with close-to-road conditions.

You can try out an interactive version of this Maple application at www.maplesoft.com/vehicle