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VEHICLE AXLE: FROM LINKAGE DESIGN TO PROTOTYPE VISUALIZATION

DJH Engineering Technical Newsletter

Fast and reliable development process

Today OEM's and their Suppliers need the reliable R&D process that is faster than ever before. This technical letter shows how DJHEC helps their customers provide a competitive advantage in the form of substantial reductions in the time-to-market for a new product of a vehicle axle. With over 30 years of experience, DJHEC is able to help specify and address functional requirements that axles shall meet. This often consists of many parameters that have effects on safety, comfort, health and damage prevention. The parameters vary based on the type of the vehicle. In the development phase the fundamental principles for an automotive axle with the independent suspension start with kinematic studies of parameters that further affect the dynamic behavior of the vehicle.

Key benefits:

- Fast and reliable R&D process to reduce time-to-market of a new product of an automotive axle
- Over 30-year design experience combined with the state-of-the-art kinematic studies and MBD simulations
- Customized plots of kinematic characteristics
- Fast data exchange to determine the effect of kinematic parameters on dynamic response of the whole vehicle
- Ability to integrate CAD components either to review clearance w.r.t the rest of vehicle or perform FEA simulations to assess structural integrity of the axle components
- Comparison of prediction to measured data
- Prototype visualization

Mechanism Design - Application

To understand the seminal mutual interaction of the members in a linkage system, DJHEC engineers create skeleton mechanisms in state of the art CAD products. This is particularly useful in order to meet the customized criteria; leverage DJHEC gained knowledge; and conform to industry standards – for example set by the Society of Automotive Engieners (SAE). What is more, it allows the engineers to create mechanisms for a wide range of the modern vehicles that are in the early development phase. Fig.1 shows a skeleton mechanism of a front steerable automotive axle. The mechanism consists of the link members, which are connected through a variety of constraints to define the proper and predictive motion of the axle linkage system. The mechanism can be further used for numerous kinematic studies. As far as the front steerable axle is taken into consideration, the parameters play a key role:

- **Bounce (steer) angle**
- **Kingpin axis inclination**
- **Caster angle**
- **Camber angle**
- **Scuff**
- **Scrub radius**
- **Roll center point**
- **Ackerman error**
- **Driveline angles**
- **Anti-dive**
- **Body-roll**

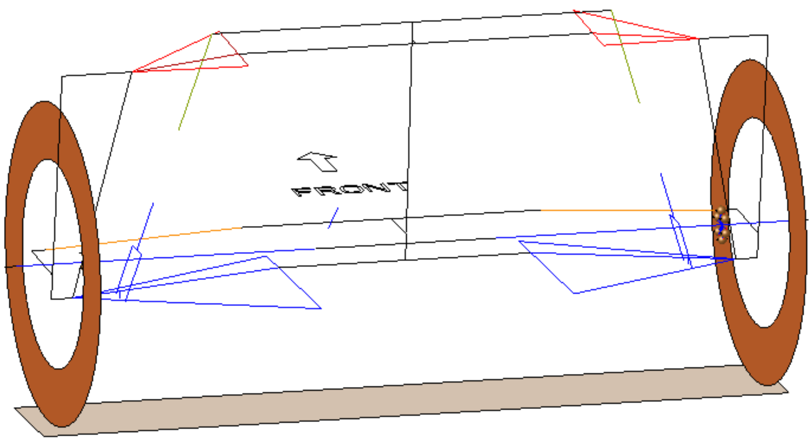

Figure 1. Automotive front axle - Skeleton

Mechanism movement study

The crucial advantage of the mechanisms is to carry out kinematic motion studies. The studies express the axle movement for the whole range of the suspension travel, for instance. This results in graphs to assess kinematic characteristics that have further effect on the dynamic behavior of the vehicle. Fig. 2 – 5 show examples of characteristics that are dependent on the suspension travel which can be analyze in detail and optimized.

TOE IN/OUT - the static toe-in angle is the angle that results in a standing vehicle (reference status), between the vehicle center plane in the longitudinal direction and the line intersecting the center plane of one left or right wheel with the road plane. It is positive, when the front part of the wheel is turned towards the vehicle longitudinal center plane and negative ('toe-out') when it is turned away. If it is plotted as a characteristics dependent on the suspension travel, it results in steering angle also known as bump-steer characteristics.

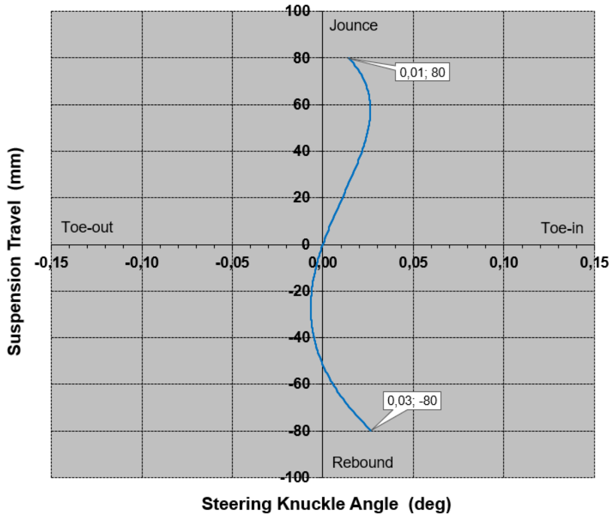

Figure 2. Steering angle δ (toe-in/out) curve during travel +/-80mm

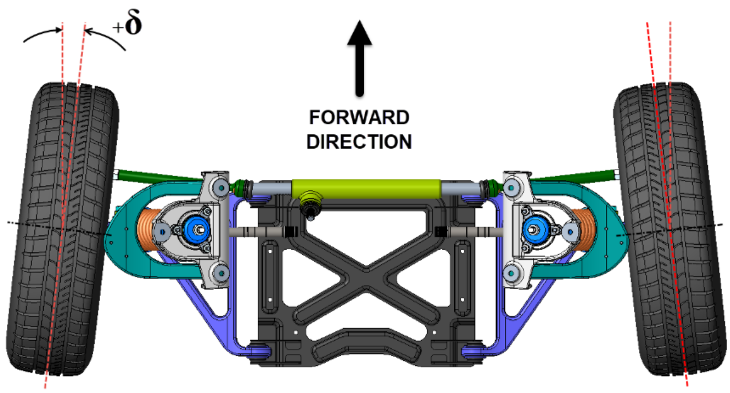

Figure 3. Steering angle δ (toe-in/out) measurement scheme

CAMBER ANGLE – camber is the angle between the wheel center plane and a plane vertical to the of the road. Positive camber is the inclination of the wheel plane outwards from the vertical Fig.4. The automotive axle with the independent suspension have camber set to negative values for the jounce suspension travel, as shown in Fig.5.

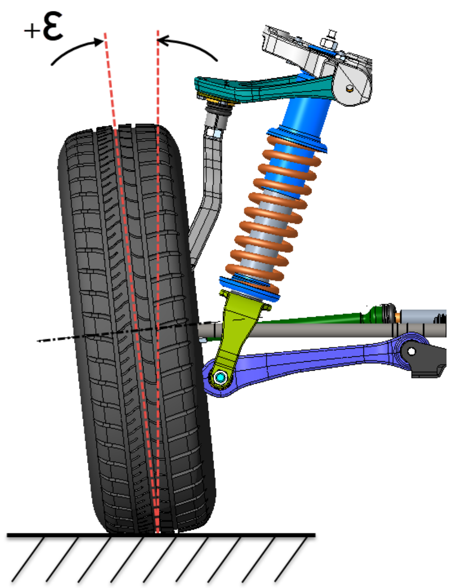

Figure 4. Camber angle ε measurement scheme

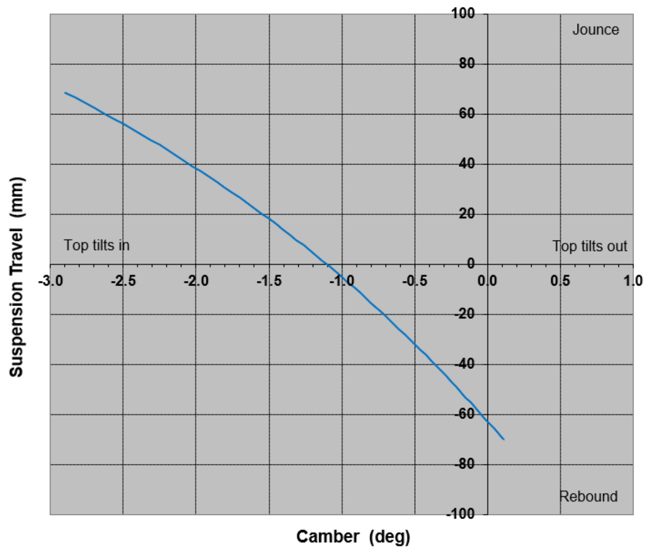

Figure 5. Camber angle ε curve during travel +/-80mm

Multi-body dynamic simulation

Once the baseline kinematic parameters of an axle are determined, the DJHEC analysts conduct MBD simulations to assess dynamic behavior of the whole vehicle for a large array of dynamic maneuvers. As an example, Fig. 6 - 7 show a ride and handling simulation to understand the body roll for various speeds. The gained knowledge from similar test drives and past simulations, helps set the predictive MBD simulations. Fig. 8 shows a comparison between the measured data and numerical simulation which depict very similar values.

Key benefits:

- Ride and handling simulation of the whole vehicle that is subjected to real world environment
- Fast and accurate prediction of the dynamic behavior of the vehicle. Proven on several projects
- Sensitivity studies of the kinematic parameters of axles and their response on dynamics
- Interface with FEA: Import flexible bodies to assess the structural integrity of the axle and its component

Figure 6. Example of the real-world test drive Slalom track

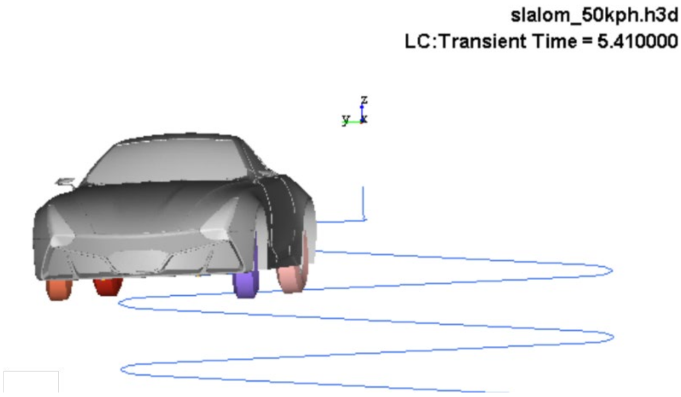

Figure 7. Example of the MotionView Simulation Slalom track

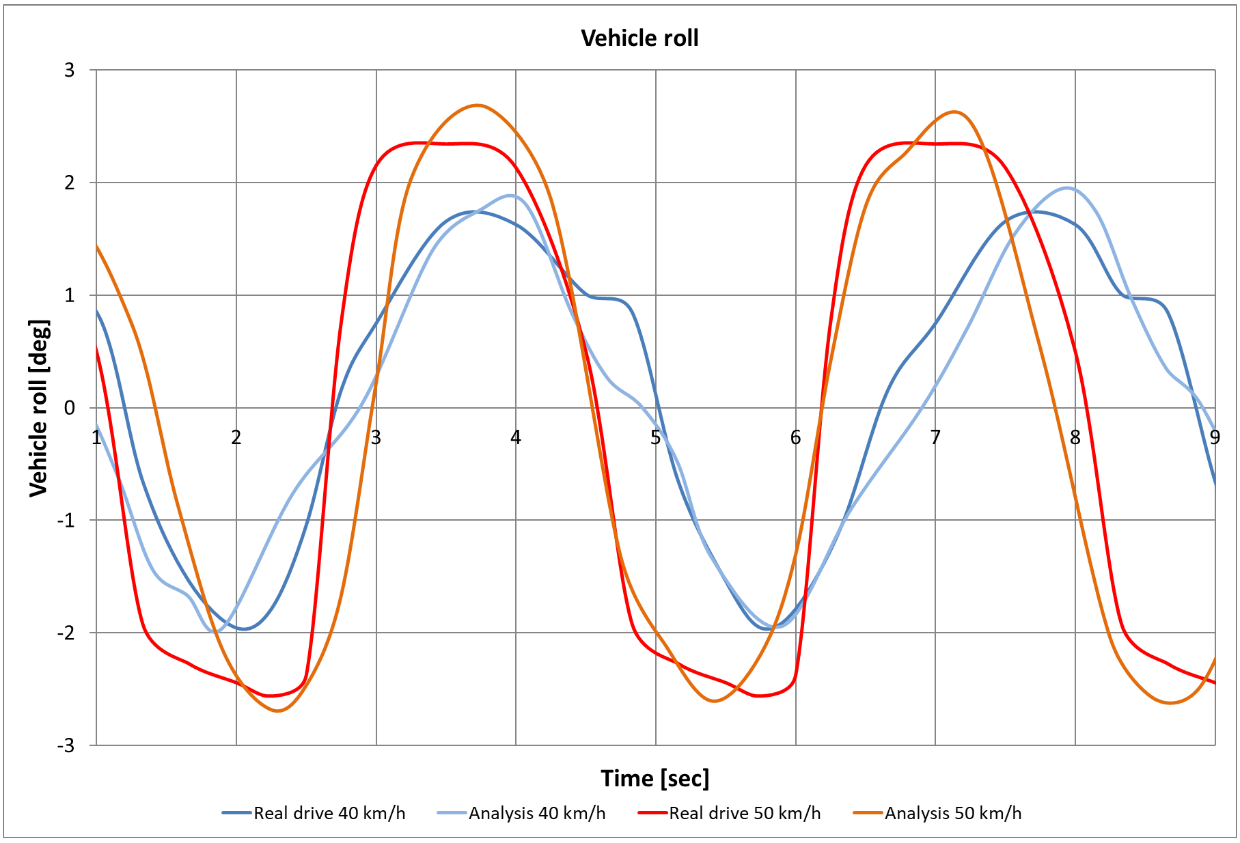

Figure 8. Vehicle roll curve comparison between Real and Virtual measurement

Clearance and interference studies – Envelope method

To make the design process even more effective, additional tasks can be run in parallel. The CAD models of the components can be designed, Fig.9. These components are then included in existing kinematic or MBD models for additional studies and validation. This helps perform either clearance studies or structural integrity FEA simulations. It also helps determine the motion restraints w.r.t the rest of the vehicle architecture. As an example, tire envelops detail the whole range of the suspension travel and steering, Fig. 10.

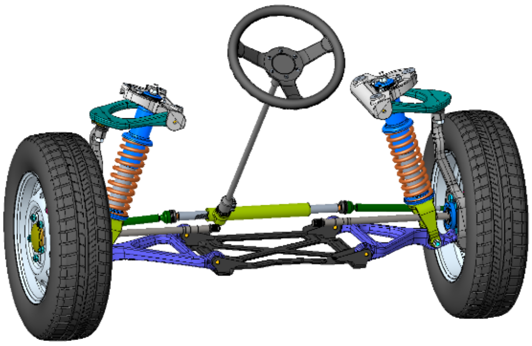

Figure 9. Automotive front axle – CAD models

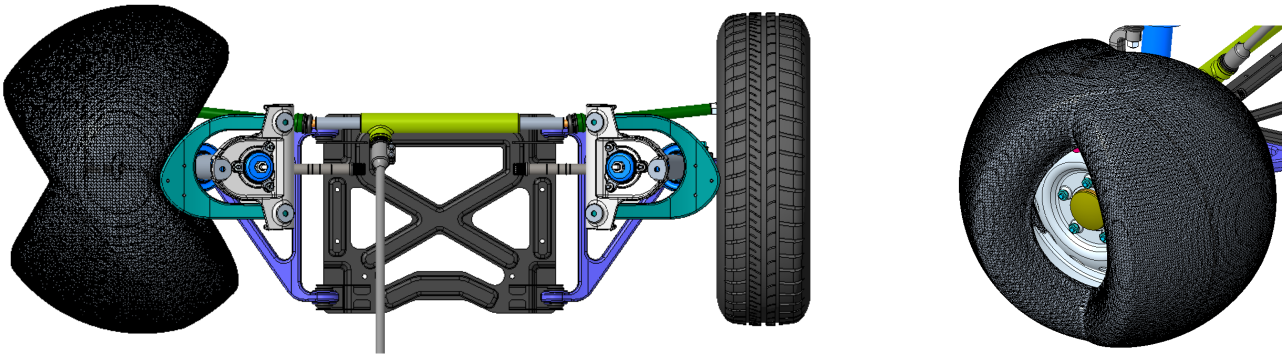

Figure 10. Tire envelope created from motion study – Steering movement

Prototype visualization – Rendering and animation

Before the final release of drawings and prototype build, DJHEC typically creates renderings for the customer to better visualize the engineering outcome. The 3D CAD geometry is imported to a rendering and animation software to create realistic product shots and animations. This often helps make final design decisions and assist the customer with the manufacturing, service, and marketing activities. The realistic materials and lightning is applied to provide the most accurate appearance and real-word lightning as shown in Fig. 11.

Figure 11. Example of the rendered front axle