

# Torque Steer Influences on McPherson Front Axles



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## 1 Background

For front wheel driven vehicles the influence of the engine torque on the steering is called Torque Steer. Especially during full acceleration the steering may pull strongly to one side, which is very disturbing to the driver. As the Torque Steer Effect is directly related to the engine torque capabilities this problem becomes more and more evident with the upcoming high power diesel and petrol engines.

Engine torque transferred through the driveshaft as well as traction force can generate a torque about the kingpin axis. Ideally the other side of the vehicle counterbalances this torque about the kingpin axis, but when different angles between driveshaft/wheel/kingpin axis and different drive torques left to right occur the residual torque influences the steering.

Root causes for Torque Steer are:

- Nonsymmetric driveshaft angles, e.g. due to
  - Nonsymmetric design of the vehicle, e.g. different driveshaft length
  - Transient movement of the engine
  - Tolerances in engine mounts
- Different driveshaft torques left to right
- Suspension geometry tolerances
- Unequal traction forces due to road surface ( $\mu$ -Split) in combination with Kingpin Offset

## 2 Objective

Vehicle dynamics testing observed severe influences of unbalanced driveshafts in terms of torsional rigidity left to right. Furthermore moving the engine within the engine mount tolerances changed the initial angular configuration of the driveshafts, what also had a big impact on Torque Steer behaviour.

There are a couple of other known influencing factors,

- Kingpin Offset (mainly package driven)
- Toe, Caster and Camber setting (general vehicle dynamics behaviour, tire wear)
- Engine Torque Roll Axis (NVH decoupling of vibration modes)
- Asymmetric mass distribution (loading of the vehicle)

that cannot be changed with regard to Torque Steer during the vehicle development phase. Therefore the driveshaft arrangement might be a design option to avoid or compensate Torque Steer.

This research was started to get a better understanding on how the driveshafts contribute to this.

### 3 Approach

A simulation model was set up for a first evaluation of effects. This model was refined until the effects noticed during vehicle dynamics testing could be qualitatively reproduced.

Simultaneously a test vehicle was equipped for measurement. The vehicle tests were used to validate the simulation model on a system and a vehicle level.

The validated model was used for parameter variations to establish well-founded knowledge of the driveshaft influence on Torque Steer.

### 4 Simulation Model

The simulation model, an ADAMS/Pre full vehicle model including a powertrain for front wheel drive, was enhanced to cover these influences. To reproduce the influence of torsional unbalanced driveshafts differential gear friction had to be added. To achieve stability during “hands free acceleration” steering rack friction was introduced.

#### 4.1 Differential Friction

As researched by the Powertrain Testing Department differential friction occurs as soon as there is differential speed between the left and the right driveshaft. The value of the frictional torque only depends on the differential input torque, not on the speed difference. This can be written as:

$$T_{friction} = T_{input} * m * SIGN(w_{left} - w_{right}) \quad (4.1)$$

To increase numerical stability the SIGN function is replaced with a STEP function in the ADAMS/Solver Dataset.

$$T_{friction} = T_{input} * m * STEP(w_{left} - w_{right}, -d_w, -1, d_w, 1) \quad (4.2)$$

In the validation process  $m$  and  $d_w$  had to be adjusted to the measurement drives.  $m$  was predicted well from gearbox rig tests,  $d_w$  should be as small as possible. Results converge asymptotically when lowering  $d_w$ , but making it too small causes smaller simulation steps when the speed difference changes its sign or even numerical problems and simulation halts.

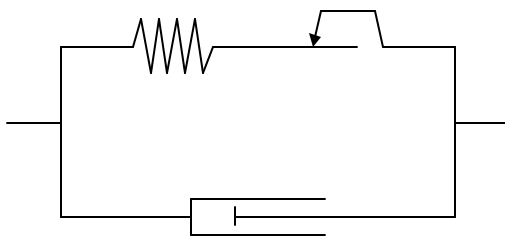
#### 4.2 Steering Rack Friction

For Steering Rack Friction the correspondent switch in ADAMS/Pre was activated resulting in a `FRICITION` statement in the ADAMS/Solver dataset. This

statement caused strong numerical problems during the simulation, which could not be resolved.

A simple friction approach was chosen to improve stability. A viscous damper paired with an in-line combination of a spring and a friction element. This was realised as a `VFORCE` user-subfunction

embedded in the ADAMS/Solver library. All three elements are set to be linear, therefore spring stiffness,



Picture 4.1: Steering Rack Friction Approach

maximum friction force and damping coefficient must be supplied for the subroutine.

This simple friction model proved to work without any instability.

## **5 Manoeuvre**

This project up to now concentrated on the influence of the driveshafts on Torque Steer during acceleration. To evaluate these influences a manoeuvre had to be defined that can be easily transferred between CAE and vehicle testing.

### **5.1 Steering Control**

During the first simulations a closed loop steering controller was used to keep the car driving on a straight line, which was skipped due to bad repeatability on the test track.

As an open loop manoeuvre two possible solutions are to accelerate “hands free” and evaluate the steering wheel angle or to drive with a fixed steering wheel and assessing the steering wheel torque. Both methods were driven on the proving ground.

### **5.2 Throttle Control**

For throttle control was defined to drive with a constant speed of 2000rpm, which reflects maximum torque. When the vehicle is driving quasistatic at this speed the throttle is suddenly pressed down for maximum acceleration up to 4500rpm. At this engine speed the throttle is released suddenly to apply maximum engine brake, which reverses the Torque Steer effect.

This manoeuvre was driven in first and second gear and proved good repeatability on the track.

### **5.3 Future research**

Some important aspects of Torque Steer remain to be investigated:

- Acceleration during cornering
- Acceleration over single wheel bump impacts
- Acceleration over double wheel bump impacts
- Acceleration on  $\mu$ -Split
- Quasi static Torque Steer at high speed or during hill climbing

## **6 Measurement**

The measurements were carried out at Ford's Lommel Proving Ground, Belgium.

The test vehicle was equipped with:

- Acceleration and yaw rate sensor
- String pots on all wheels
- Correvit sensor for vehicle speed measurement
- Measurement rims to acquire wheel forces in all six degrees of freedom

One aim of the measurement was to evaluate the influence of driveshaft angles on Torque Steer. To reduce transient, uncontrollable effects rigid engine mounts replaced the rubber bushings. These engine mounts were crafted to be

adjustable  $\pm 10\text{mm}$  in the vehicle driving direction as well as the vertical direction. With these adjustable mounts the relative angle between left and right driveshaft was adjusted by moving the engine into different positions. In each position several reference points of the engine were measured with a 3D-system to document the engine position for the measurement.

Several engine position configurations were tested with torsional unbalanced as well as balanced driveshaft combinations.

## 7 Validation of Simulation Model

### 7.1 System Level

On system level the elastokinematic behaviour of the model was adjusted to comply with test vehicle measured on the Lommel K&C Rig.

Some hardpoints of the simulation model had to be moved in their tolerance range to reflect the kinematical behaviour of the test vehicle.

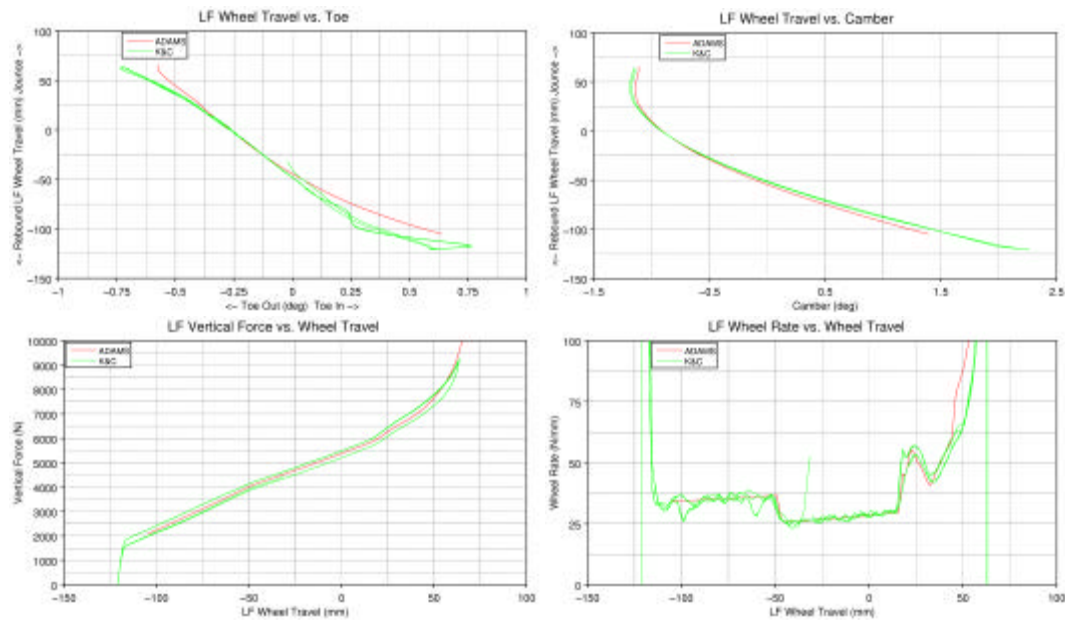


Figure 7.1: Front Axle Kinematics

Further some bushing stiffness had to be scaled to reflect the elastokinematic.

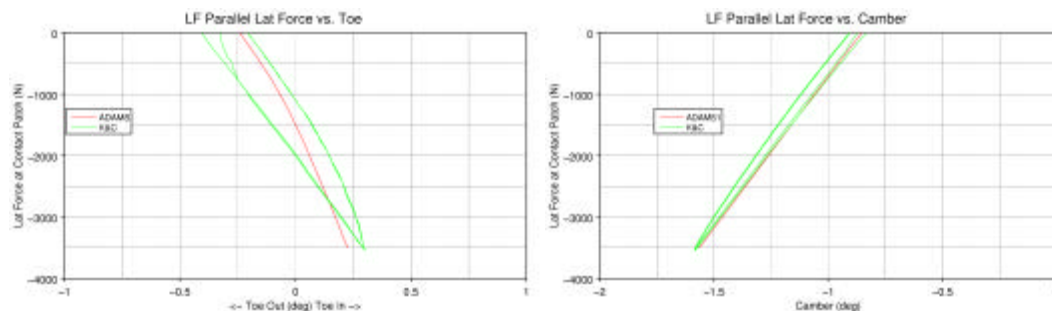
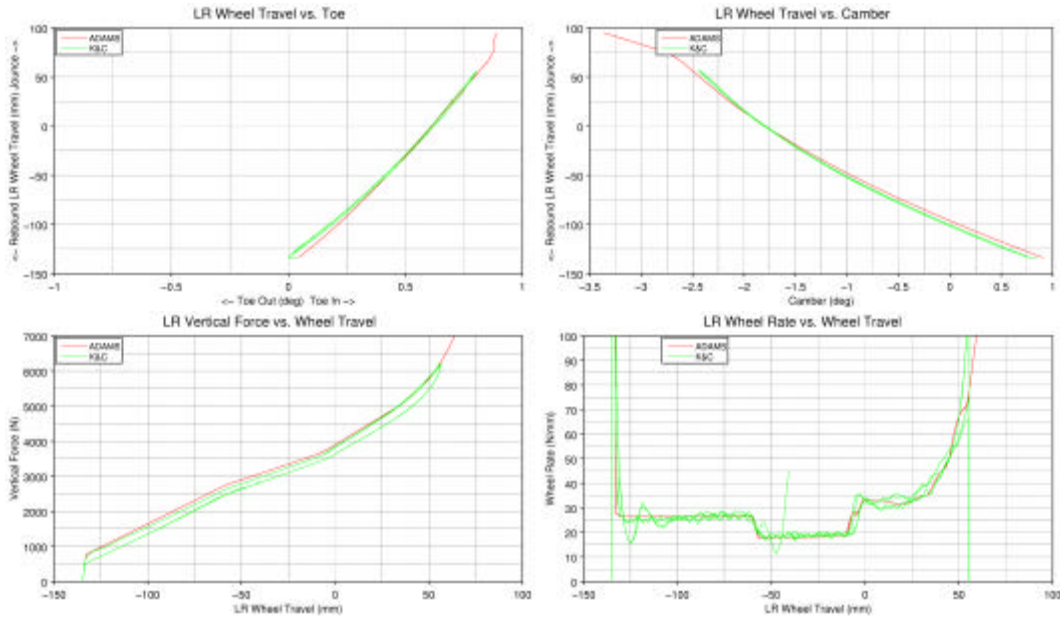
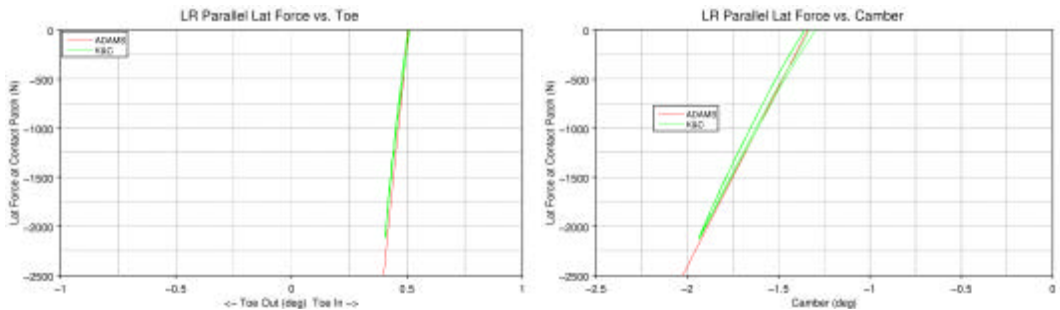


Figure 7.2: Front Axle Compliance



**Figure 7.3:** Rear Axle Kinematics



**Figure 7.4:** Rear Axle Compliance

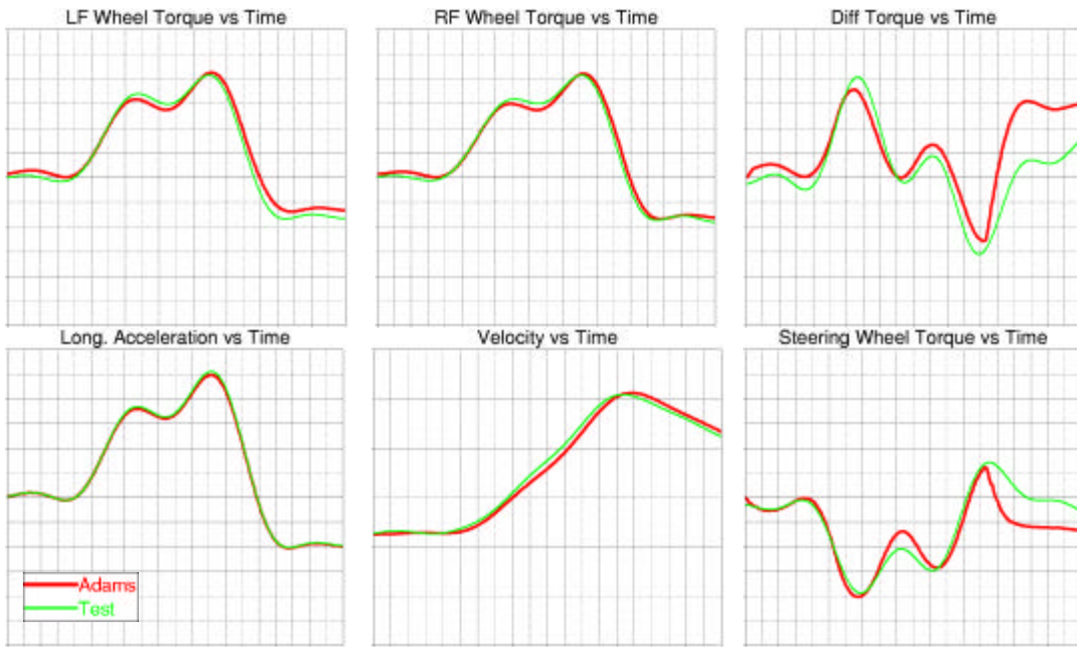
## 7.2 Vehicle Level

To achieve the full vehicle behaviour during the Torque Steer test, the introduced parameters for differential friction and steering gear friction had to be re-adjusted.

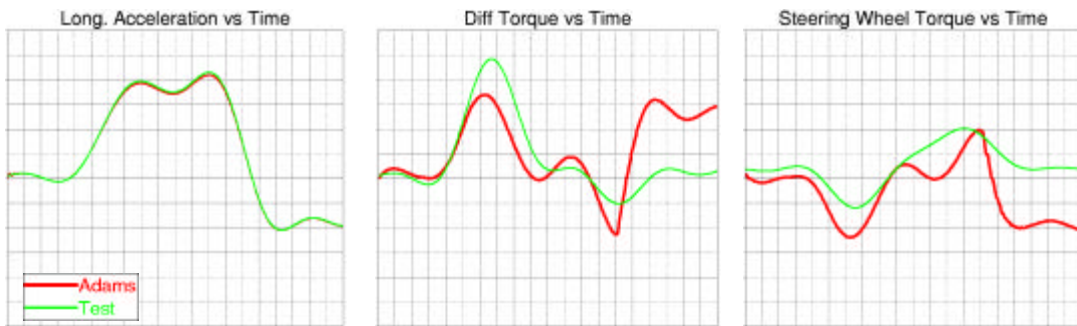
For the validation runs the simulation models were prepared to follow the longitudinal acceleration of the corresponding test run.

In figure 7.5 the measurement data are plotted together with simulation data. All graphs show a good correlation except for the differential friction torque during throttle off. This friction torque directly influences the steering wheel torque. The root cause of this deviation between test and simulation is not finally clarified, but as torque steer is mainly evident during acceleration and the deviation occurs during deceleration these models are credible.

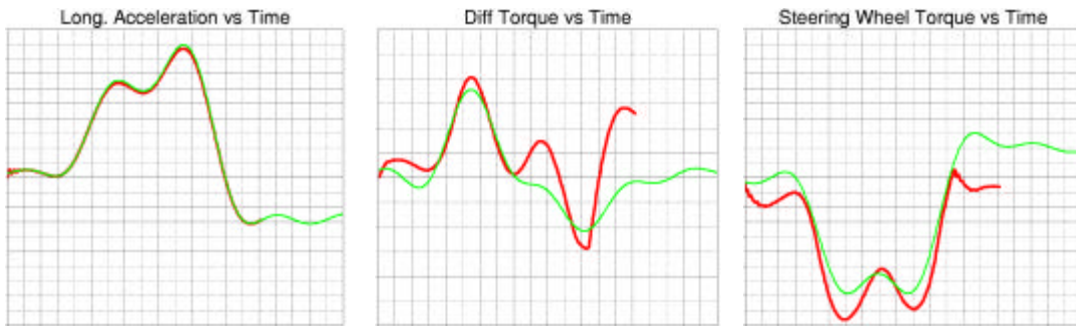
Further, figures 7.6 to 7.8 show the correlation of differential friction torque and steering wheel torque for different engine mounting positions.



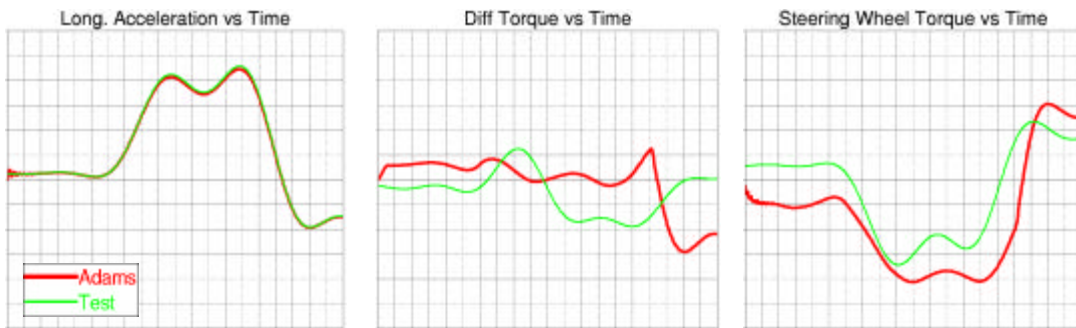
**Figure 7.5:** Configuration 2, 1<sup>st</sup> gear acceleration, Engine centre position



**Figure 7.6:** Configuration 3, 1<sup>st</sup> gear acceleration, Engine tilted to left



**Figure 7.7:** Configuration 4, 1<sup>st</sup> gear acceleration, Engine tilted to right



**Figure 7.8:** Configuration 5, 1<sup>st</sup> gear acceleration, Engine tilted to right, balanced driveshafts

## 8 Next Steps

The validated model is used to set up a “Design of Experiments” in ADAMS/INSIGHT. On the basis of the resulting response surface the sensitivities of the observed factors as well as their interactions are assessed. With these sensitivities reliable predictions on the influence of changes in the car can be made. Therefore in a vehicle concept phase targets can be derived for systems and components. Additionally, a design guideline is created for mutual compensation of different influences, if tradeoffs must be made to comply with other attributes.

The enhanced model can now be used to optimise the vehicle design in an early phase of the development. The experience gained during set-up and validation of the model will help to improve pre-program simulations to cover Torque Steer disturbances before first physical prototypes are built.