Suspension Multibody Simulation

Suspension Key Performance Indicator Report

RACE user: RACE Demo
Simulation description: Double Wishbone Demo Simulation - Standard

Suspension type: Double Wishbone - Standard

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1 Statement of Non-liability

RACE software provided by race.software is intended as a suspension concept development tool. It is designed to help you to understand the performance of your suspension system. This report contains information on the performance of a suspension system as specified by the inputs you have supplied to the RACE software programme. Race.software has no control over the inputs chosen by you and takes no reponsibility for the performance of your suspension system. You are the owner of your suspension system and you are reponsible for its performance. The results of the RACE software should be used only to improve your understanding of its operation, not as a guaranteed prediction of how it will perform. It is your reponsibility as the user of RACE software to interpret the results it provides and to make your own judgement as to how your suspension will perform in real life.

2 RACE Kinematics and Compliance Analysis

RACE is a specialist multibody dynamics software for virtual suspension Kinematics and Compliance (K&C) testing. The K&C analysis is done on a complete front or rear suspension model (half car model/axle model). The K&C test cases are described in the sections below. The test inputs are simplified representations of the motion and loading a suspension system is subject to during its operation in roll, cornering, braking and traction.

The simplified inputs allow the force-response interactions of the suspension system to be measured, understood and ultimately tuned. The key to good suspension design is to develop the suspension system to move (kinematics) and deform (compliance) in a way that gives the driver confidence and delivers controlled, predictable vehicle behaviour.

2.1 RACE Kinematics tests

- **Vertical Motion**: ±50 mm parallel wheel travel.
- **Roll Motion**: ±50 mm opposite wheel travel. The test is run with the anti-roll bar connected (RACE Advanced only).
- **Steering Input**: ±50 mm steering rack travel in RACE Standard. The steering rack travel is user defined in RACE Advanced.

2.2 RACE Compliance tests

- **Lateral Force**: ±3000 N lateral load applied at the tyre contact patch. The left and right wheel loads are applied in-phase (loads applied to the left and right wheel in the same direction). The tests are run with the load applied at the contact patch (0mm trail) and with the load applied 30mm behind the contact patch (30mm trail).
- **Braking Force**: ±3000 N longitudinal load applied at the tyre contact patch. The left and right wheel loads are applied in-phase.
- **Traction Force**: ±3000 N longitudinal load applied at the wheel centre. The left and right wheel loads are applied in-phase.
- **Tyre Aligning Torque**: ±300 Nm torque applied at the tyre contact patch. The left and right wheel moments are applied in-phase.

3 Simulation Details

- **Simulation description:** Double Wishbone Demo Simulation - Standard

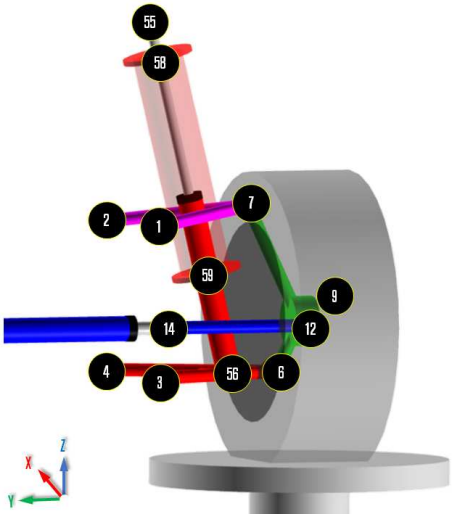

Figure 1: Suspension hardpoint numbering convention

Table 1: Suspension hardpoint co-ordinates

Hardpoint	X (mm)	Y (mm)	Z (mm)
p1	1200.00	-400.00	1303.00
p2	1500.00	-400.00	1297.00
p3	1200.00	-400.00	1000.00
p9	1350.00	-750.00	1100.00
p4	1500.00	-400.00	1000.00
p6	1350.00	-700.00	1000.00
p7	1380.00	-650.00	1330.00
p12	1200.00	-720.00	1053.00
p14	1200.00	-430.00	1050.00
p55	1350.00	-450.00	1500.00
p56	1350.00	-640.00	1000.00
p58	1350.00	-450.00	1500.00
p59	1350.00	-565.00	1200.00

Table 2: Suspension joint types

Joint	Type	Key stiffnesses	Joint attached to
p1	Standard bush	Radial 8 kN/mm; Axial 0.5 kN/mm	Chassis
p2	Standard bush	Radial 8 kN/mm; Axial 0.5 kN/mm	Chassis
p3	Standard bush	Radial 10 kN/mm; Axial 0.5 kN/mm	Chassis
p4	Standard bush	Radial 10 kN/mm; Axial 0.5 kN/mm	Chassis
p6	Ball joint	Radial 50 kN/mm; Axial 50 kN/mm	Knuckle
p7	Ball joint	Radial 50 kN/mm; Axial 50 kN/mm	Knuckle
p12	Ball joint	Radial 50 kN/mm; Axial 50 kN/mm	Knuckle
p14	Ball joint	Radial 50 kN/mm; Axial 50 kN/mm	Steering rack
p19	Wheel bearing	Conical 10 kNm/Deg	Wheel hub
p55	Top mount	Radial 3 kN/mm; Axial 0.5 kN/mm	Chassis
p56	Ball joint	Radial 50 kN/mm; Axial 50 kN/mm	Lower control arm
p58	Spring upper	Rigid attachment	Damper rod (coilover)
p59	Spring lower	Rigid attachment	Damper tube (coilover)
p72	Rod guide	Conical 5 kNm/Deg	Damper rod

Table 3: Suspension parameters

Parameter	Value	Unit
Spring rate	30.00	N/mm
Spring preload	5000	N
Tyre loaded radius	300.0	mm
Wheelbase	2200.0	mm

Table 4: RACE simulation stats

Phase	CPU Time (s)	Status
Pre-processing	114.3	Complete

Phase	CPU Time (s)	Status
Lateral ip0	3.0	Complete
Aligning ip	3.0	Complete
Lateral ip30	3.0	Complete
Traction	3.3	Complete
Braking	3.4	Complete
Vertical	4.3	Complete
Steering	4.8	Complete
Simulation Total	24.8	

Phase	CPU Time (s)	Status
Post-processing	82.9	Complete

4 Suspension Key Performance Indicator Summary

- The suspension KPIs are all calculated for the left wheel of the suspension
- The KPI summary table is split into kinematics and compliance sections
- The kinematics KPIs table can be found in §4.1
- The compliance KPIs table can be found in §4.2
- Click on the KPI name in the tables to link to the KPI graph
- The KPI graphs show the multibody simulation signals plotted to generate the KPI in blue
- The point at which a KPI value was taken from the curve is shown by a red cross
- Where the KPI is calculated from the gradient of the curve, the curve fit is shown by a red line
- Click on the metric unit in the tables to link to the metric sign convention definitions in §6

4.1 RACE Kinematics KPIs

KPI	Unit	Value
STATIC GEOMETRY		
Static camber	deg	-0.03
Static toe	deg	0.04
Track width at contact patch	mm	1500.4
Damper ratio	mm/mm	0.69
Spring ratio	mm/mm	0.69
STEERING INPUT		
Kingpin inclination - with steer	deg	8.4
Castor angle - with steer	deg	5.1
Castor trail - with steer	mm	17.2
Scrub radius - with steer	mm	21.1
Wheel centre longitudinal offset - with steer	mm	-9.6
Wheel centre lateral offset - with steer	mm	64.4
Steering ratio - on-centre	deg/mm	0.37
Steering rack travel - centre to full lock	mm	50
Lock angle at full right rack travel	deg	18.4
Lock angle at full left rack travel	deg	-19
Percent ackermann at full rack travel	%	19
VERTICAL MOTION		
Bump camber	deg/m	-20.4
Bump steer - on centre	deg/m	-2.9
Bump steer - 25mm bump	deg/m	-1.6
Bump steer - 25mm rebound	deg/m	-4.2
Bump castor (knuckle rotation)	deg/m	3.7
Kinematic wheel centre recession	mm/m	9
Contact patch lateral migration	mm/m	72.2
Wheel rate - on centre	N/mm	26.4
Wheel rate - 25mm bump	N/mm	28.1
Wheel rate - 25mm rebound	N/mm	25.1

4.2 RACE Compliance KPIs

KPI	Unit	Value
BRAKING FORCE		
Brake steer	deg/kN	-0.01
Braking castor compliance (knuckle rotation)	deg/kN	-0.464
Contact patch longitudinal compliance	mm/kN	3.6
Front anti-dive; Rear anti-lift	N/N	0.011
Front anti-dive; Rear anti-lift	deg	0.6
LATERAL FORCE		
Roll centre height - wheel load variation	N/N	0.072
Camber compliance in-phase 0mm trail	deg/kN	0.061
Contact patch compliance in-phase 0mm trail	mm/kN	0.393
Lateral compliance steer in-phase 0mm trail	deg/kN	-0.036
Lateral compliance steer in-phase 30mm trail	deg/kN	-0.045
Contact patch stiffness in-phase 0mm trail	N/mm	2545
Roll centre height	mm	54
TRACTION FORCE		
Traction steer	deg/kN	0.016
Traction castor compliance (knuckle rotation)	deg/kN	-0.086
Wheel centre longitudinal compliance	mm/kN	0.74
Front anti-lift; Rear anti-squat	N/N	-0.009
Front anti-lift; Rear anti-squat	deg	-0.5
TYRE ALIGNING TORQUE		
Aligning torque toe compliance in-phase	deg/kNm	0.32

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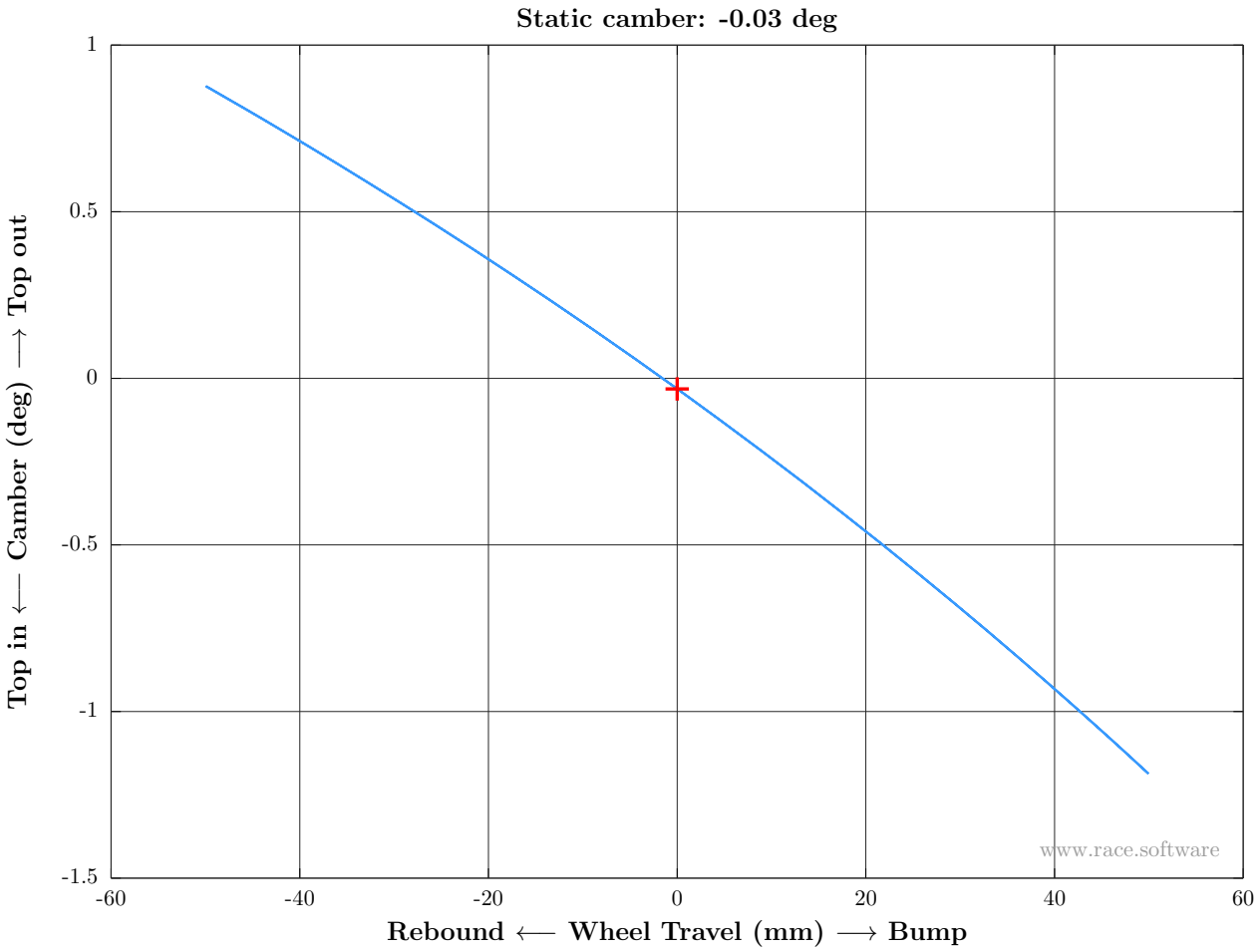

Figure 2: Vertical test: Static camber

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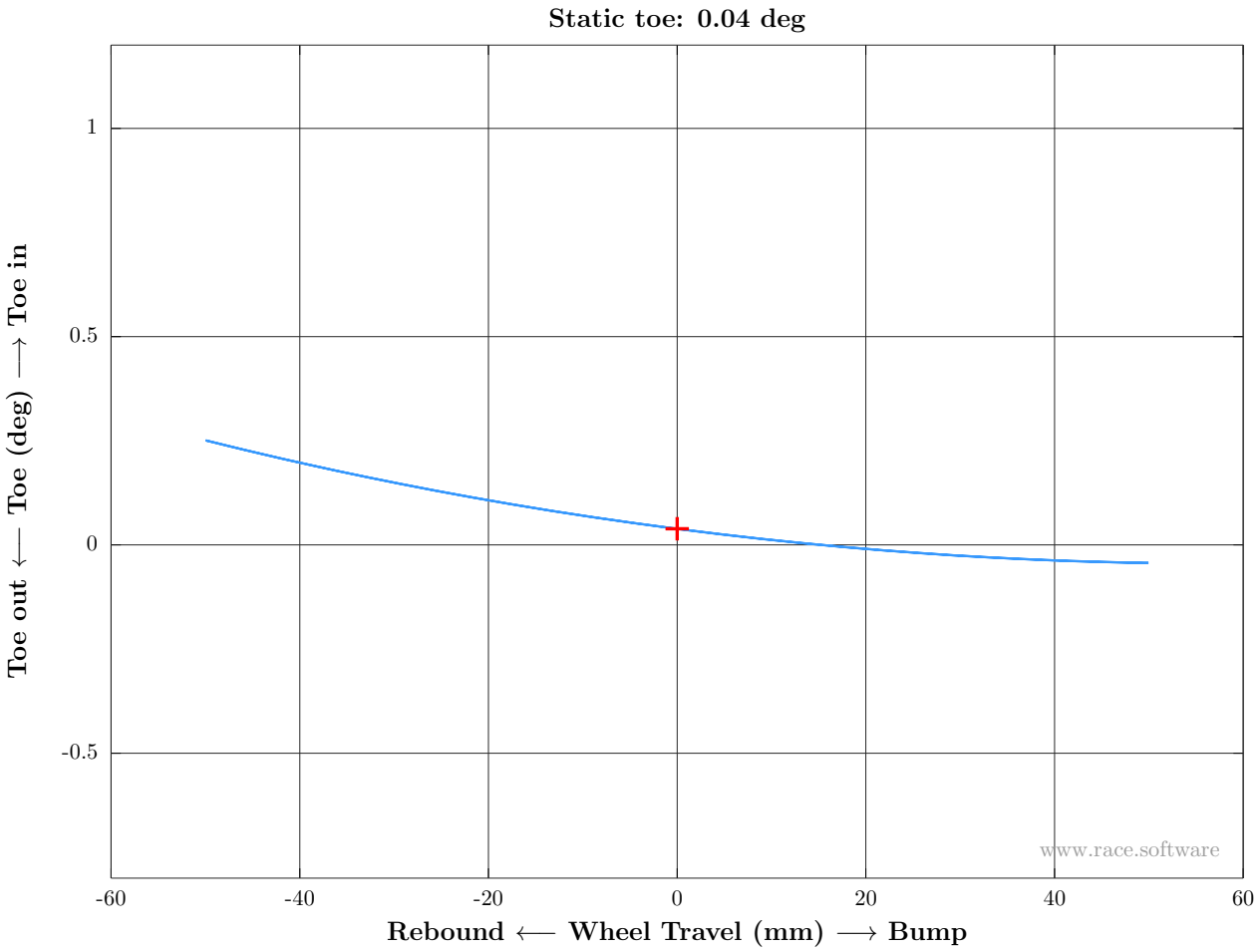

Figure 3: Vertical test: Static toe

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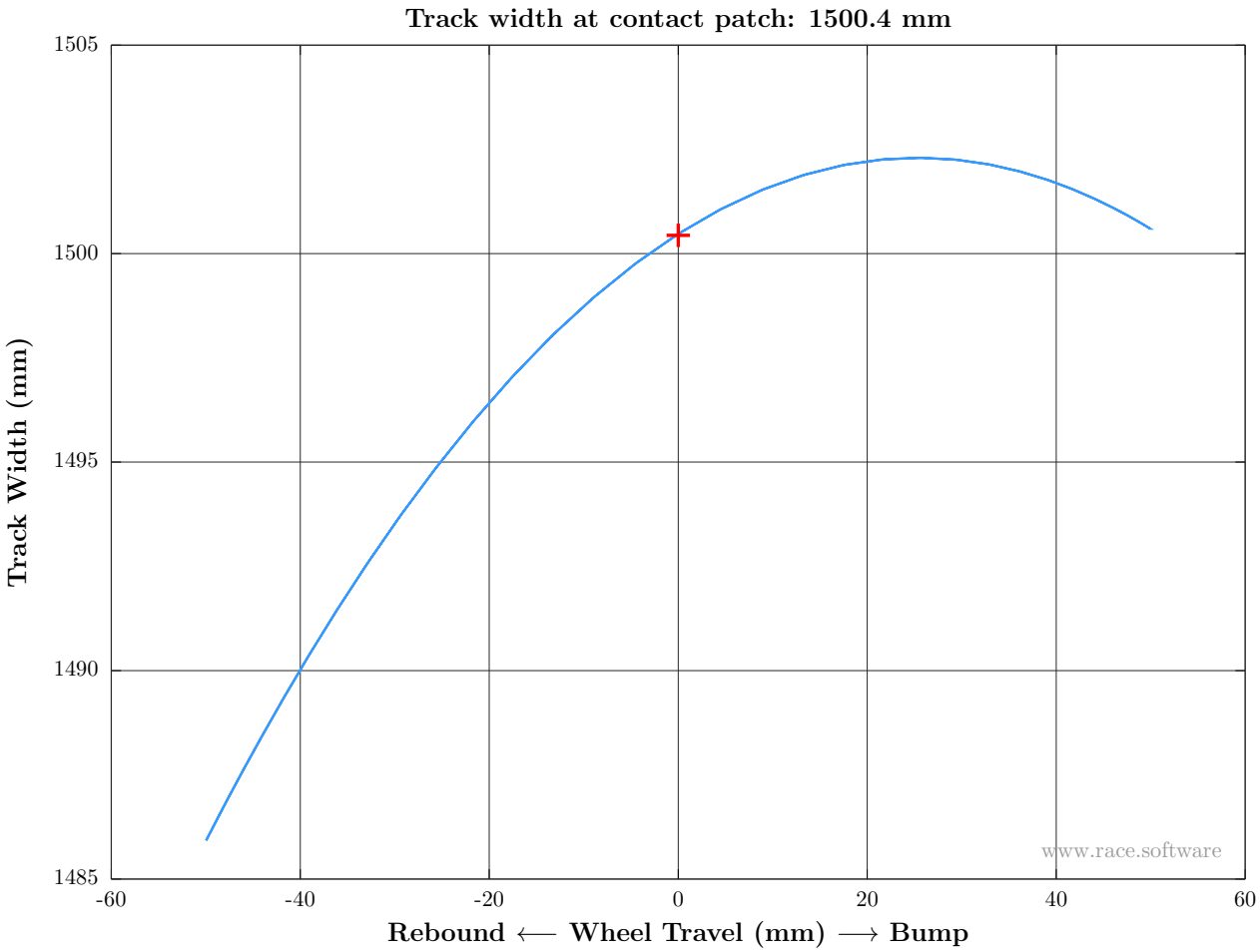

Figure 4: Vertical test: Track width at contact patch

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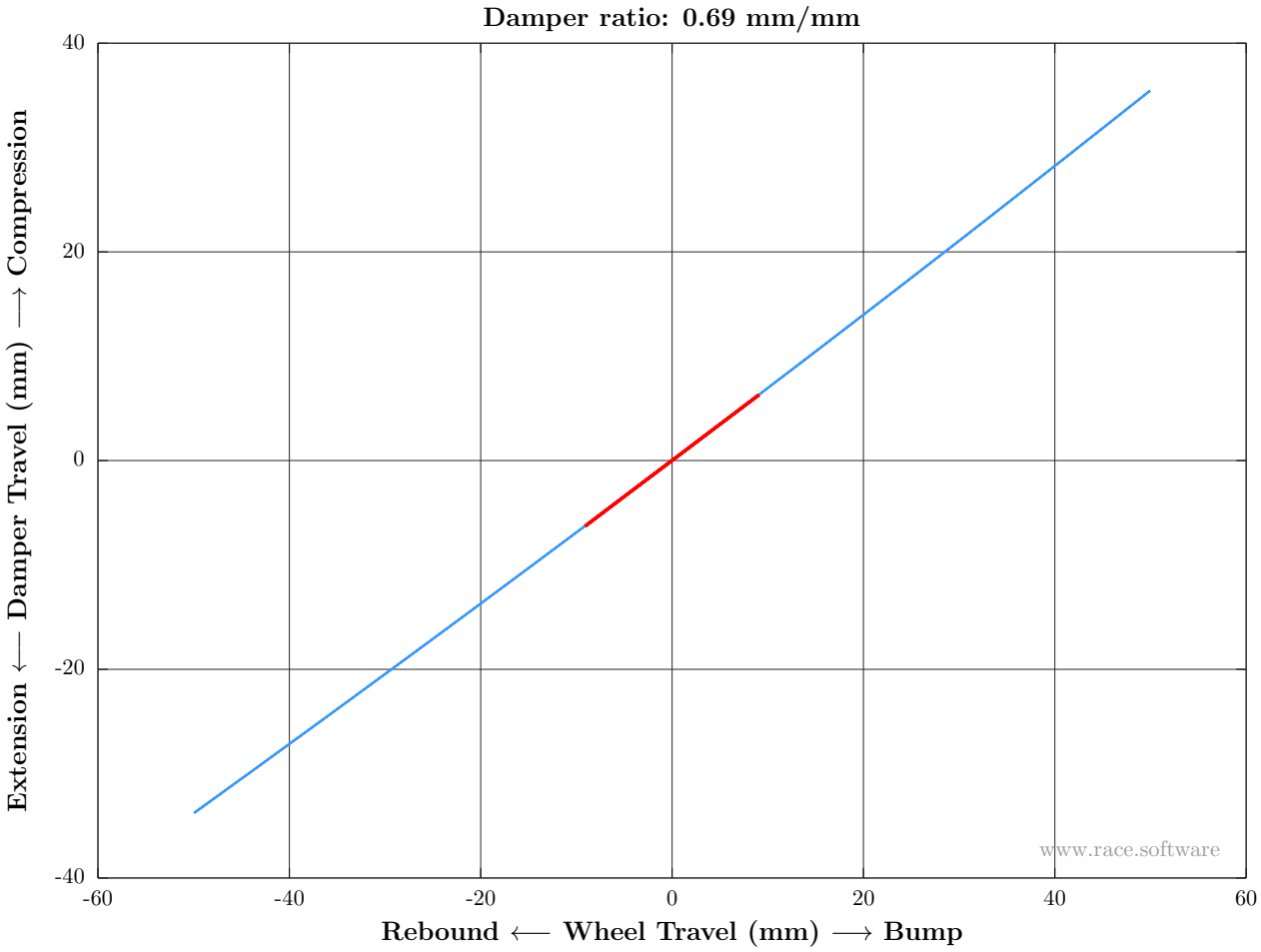

Figure 5: Vertical test: Damper ratio

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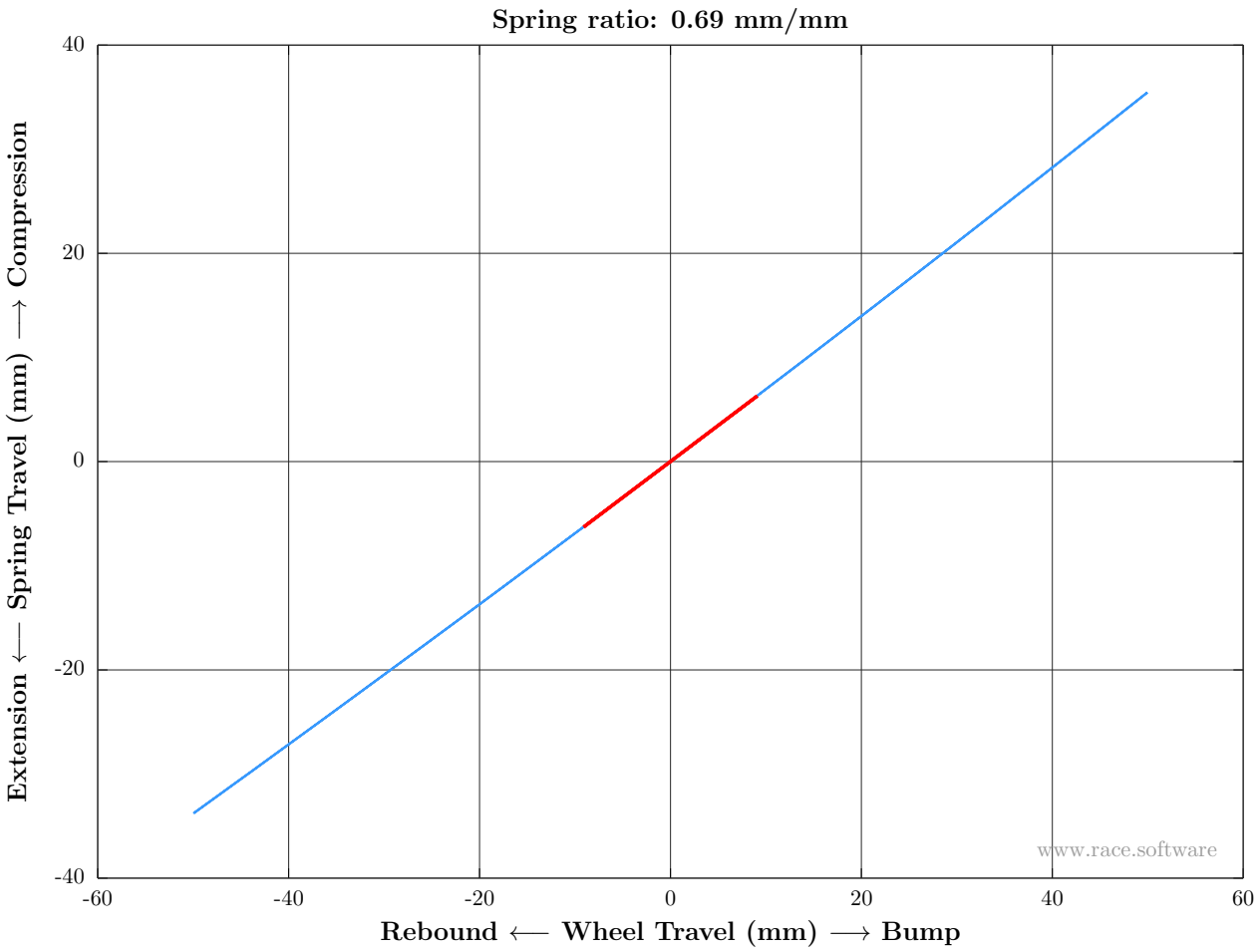

Figure 6: Vertical test: Spring ratio

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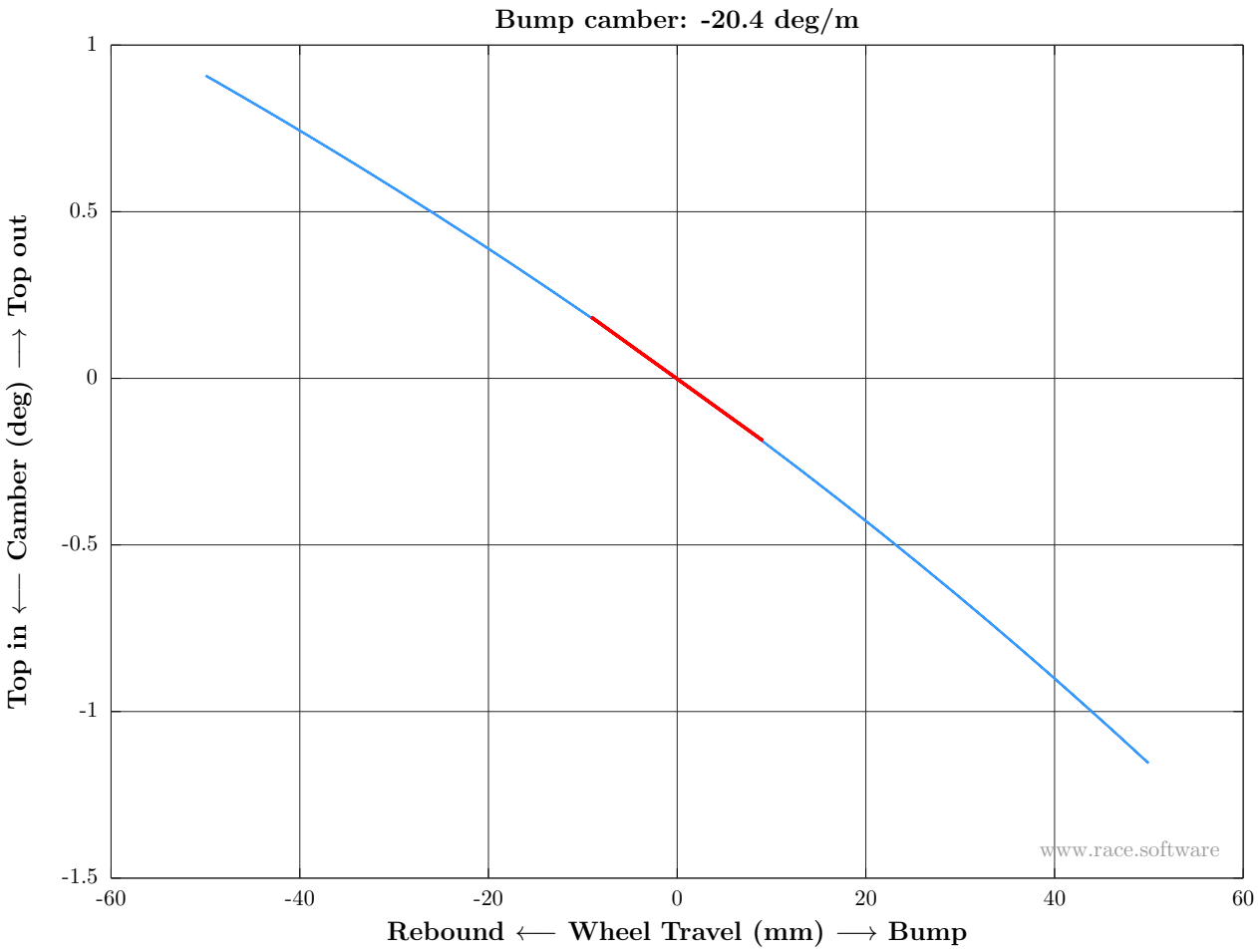

Figure 7: Vertical test: Bump camber

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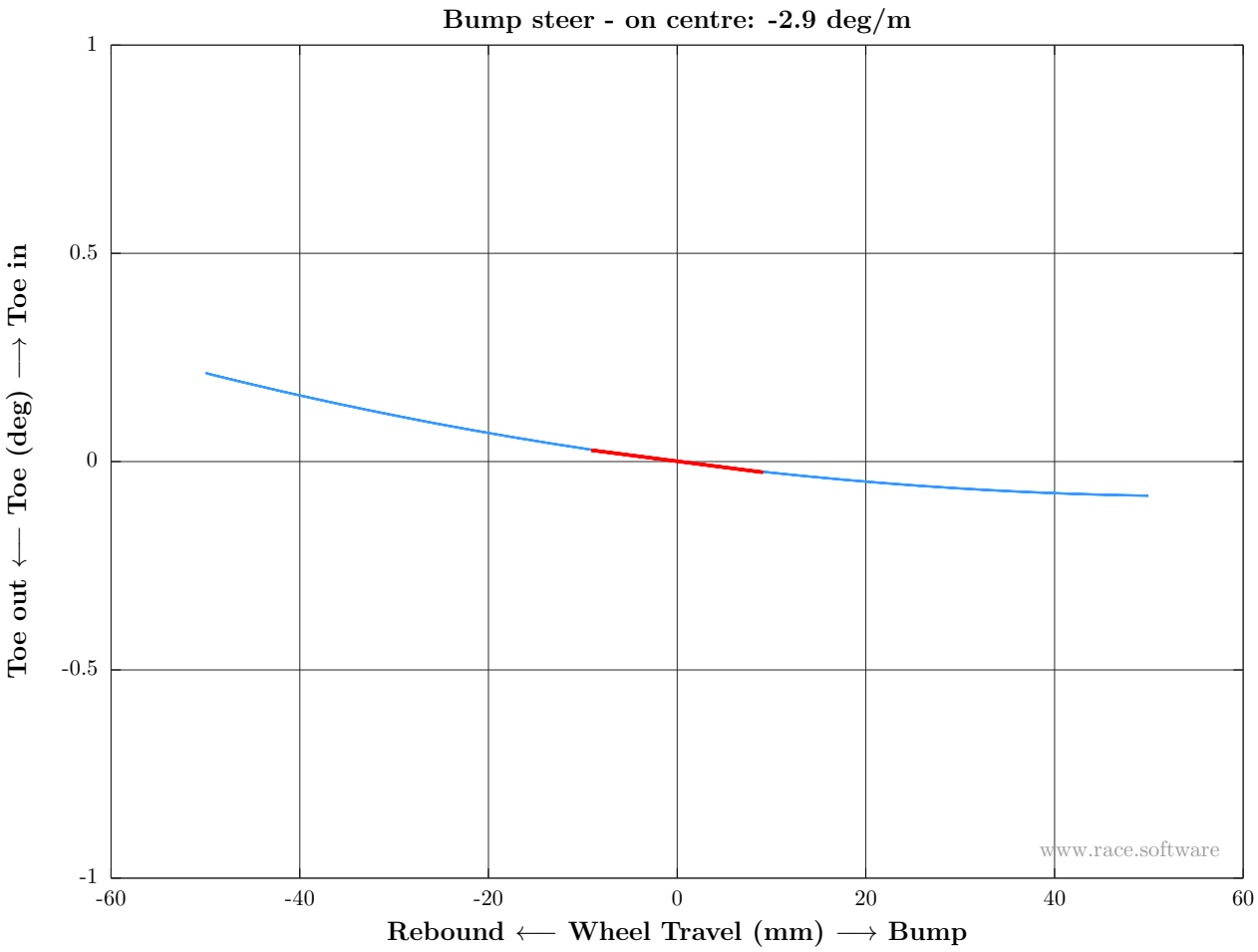

Figure 8: Vertical test: Bump steer - on centre

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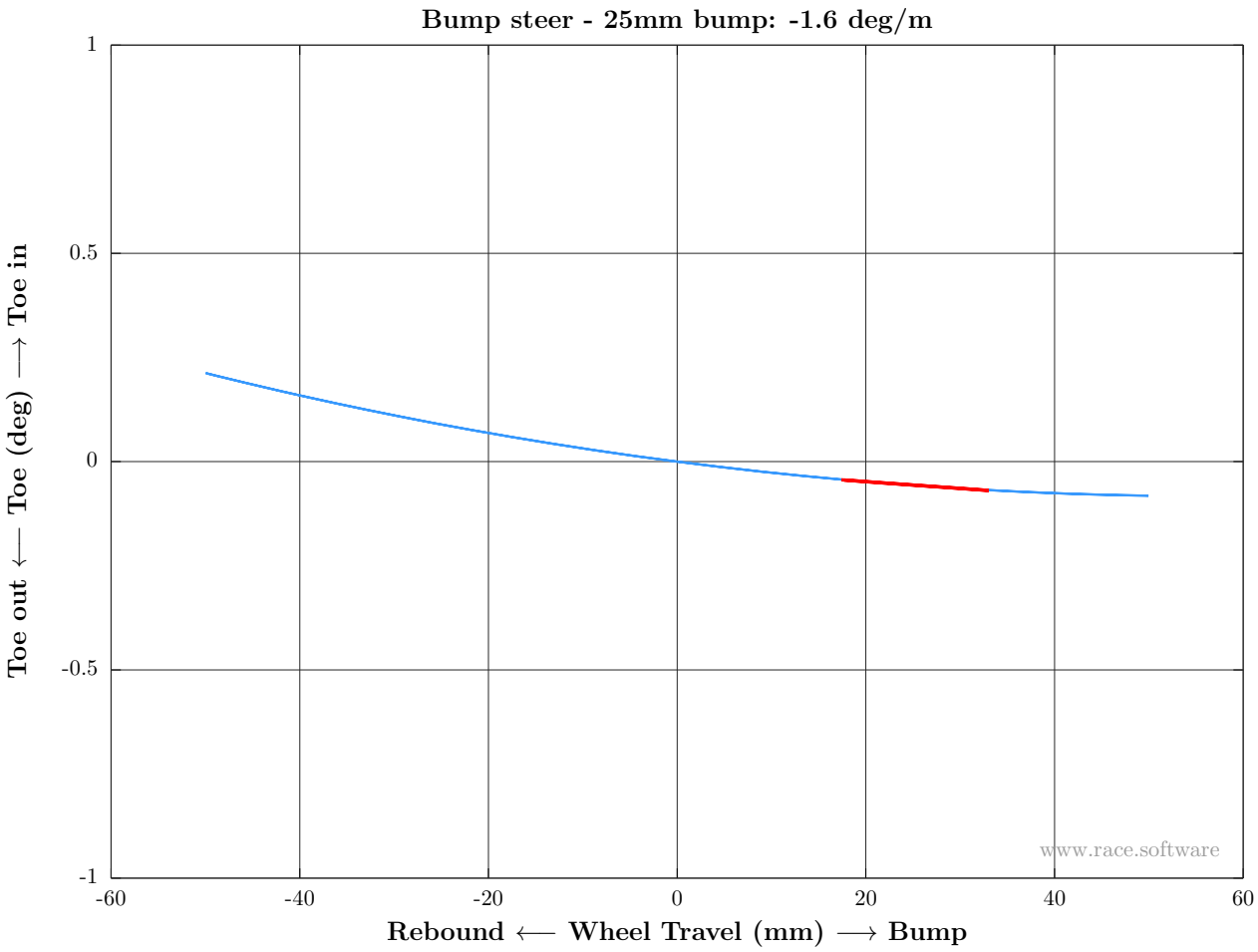

Figure 9: Vertical test: Bump steer - 25mm bump

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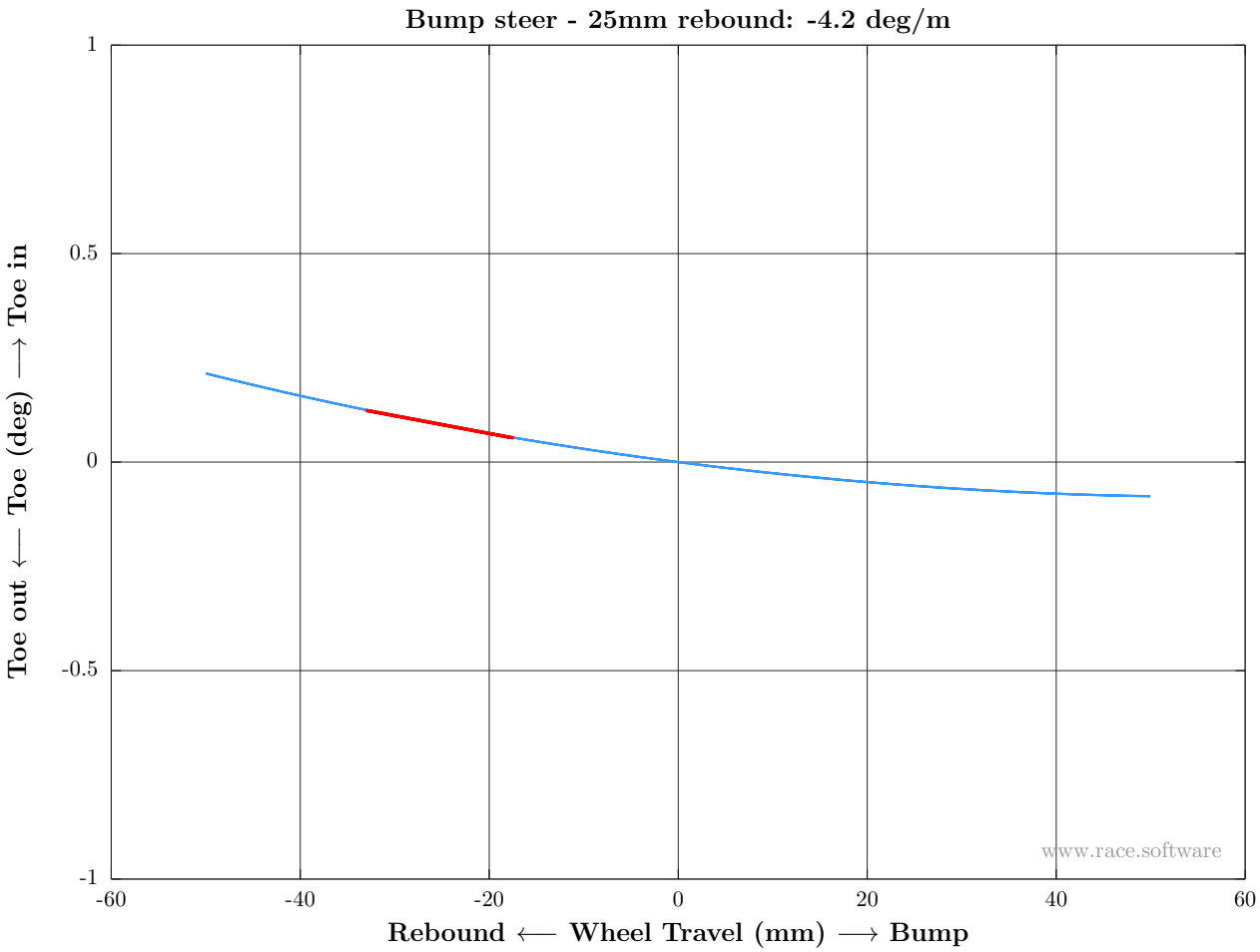

Figure 10: Vertical test: Bump steer - 25mm rebound

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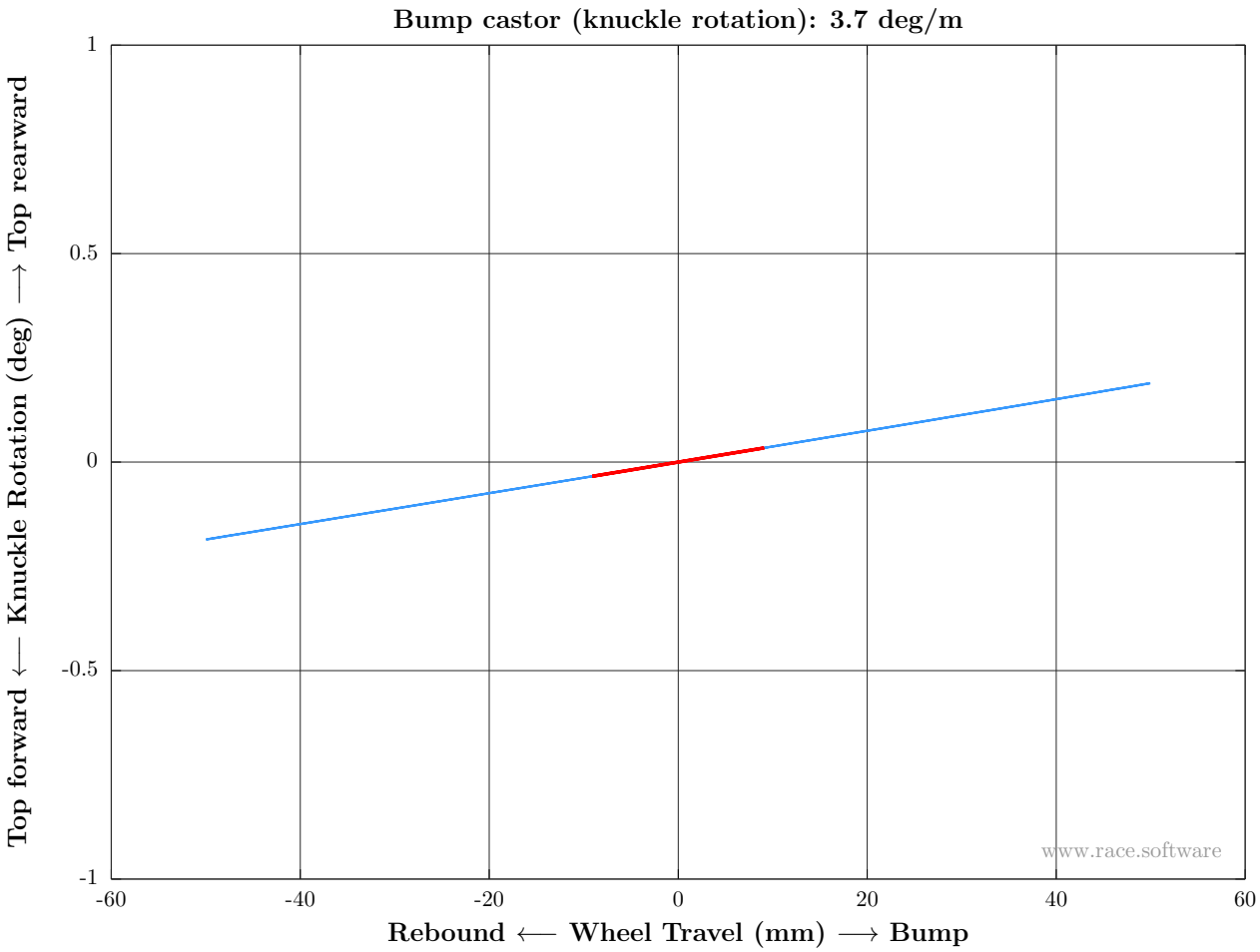

Figure 11: Vertical test: Bump castor (knuckle rotation)

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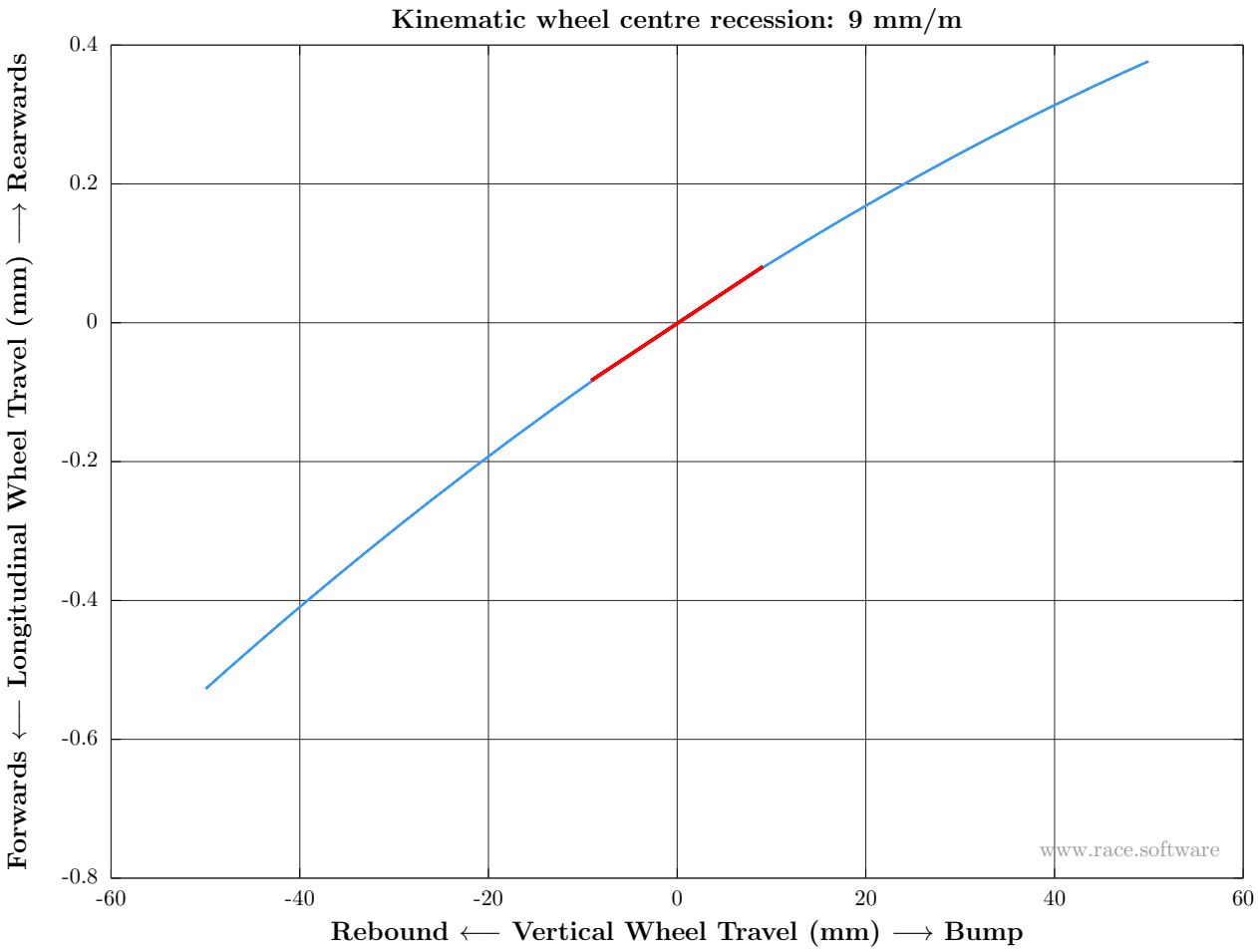

Figure 12: Vertical test: Kinematic wheel centre recession

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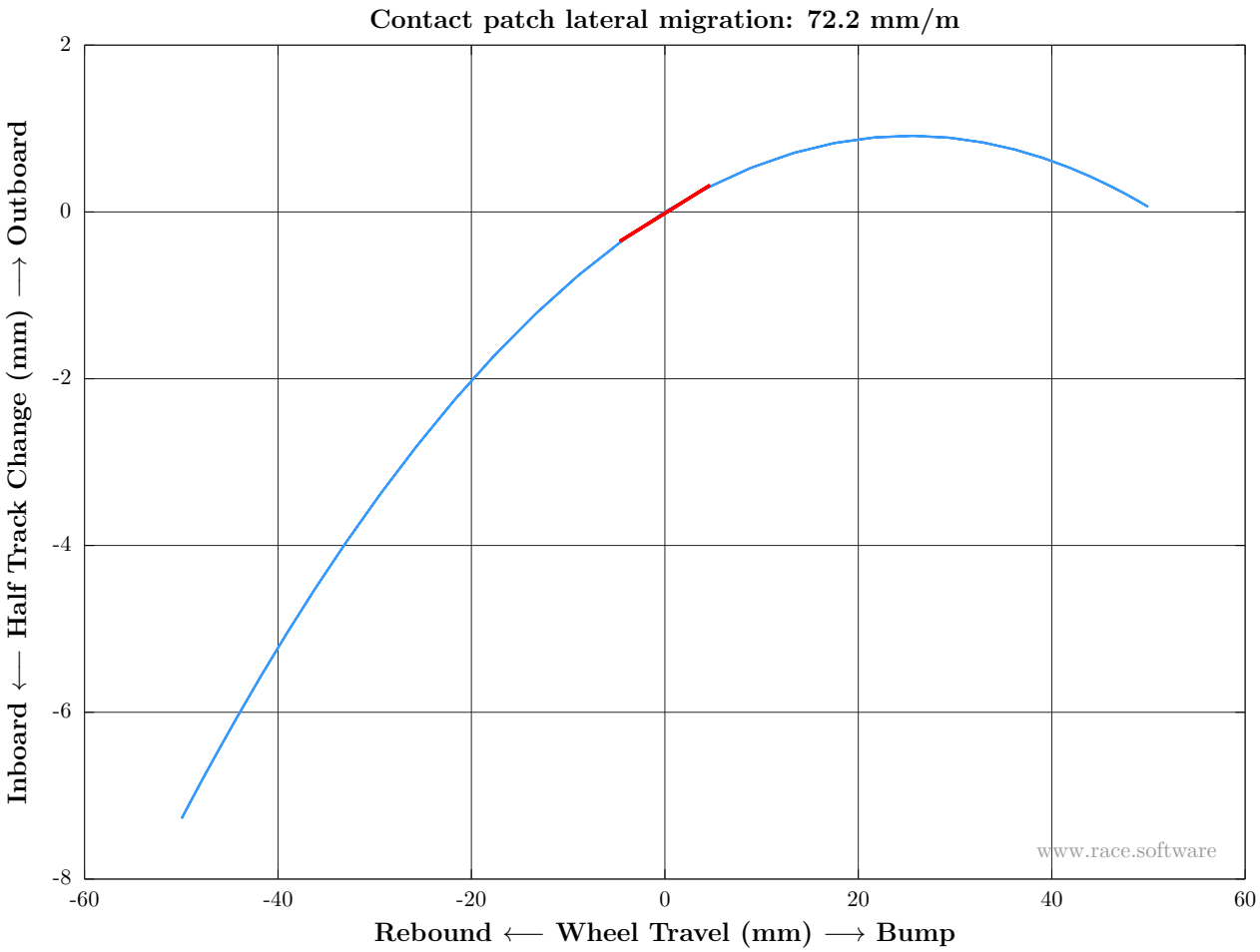

Figure 13: Vertical test: Contact patch lateral migration

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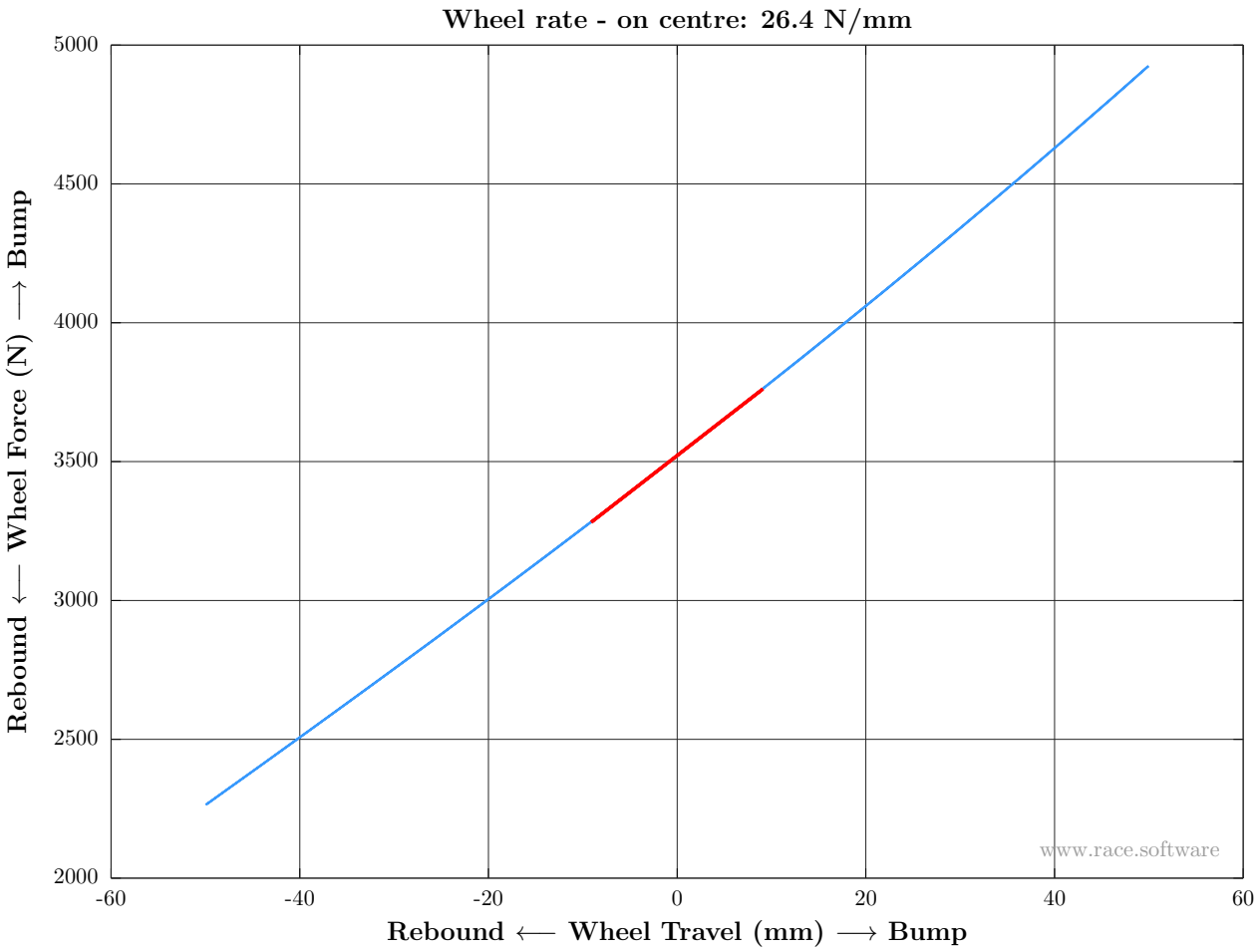

Figure 14: Vertical test: Wheel rate - on centre

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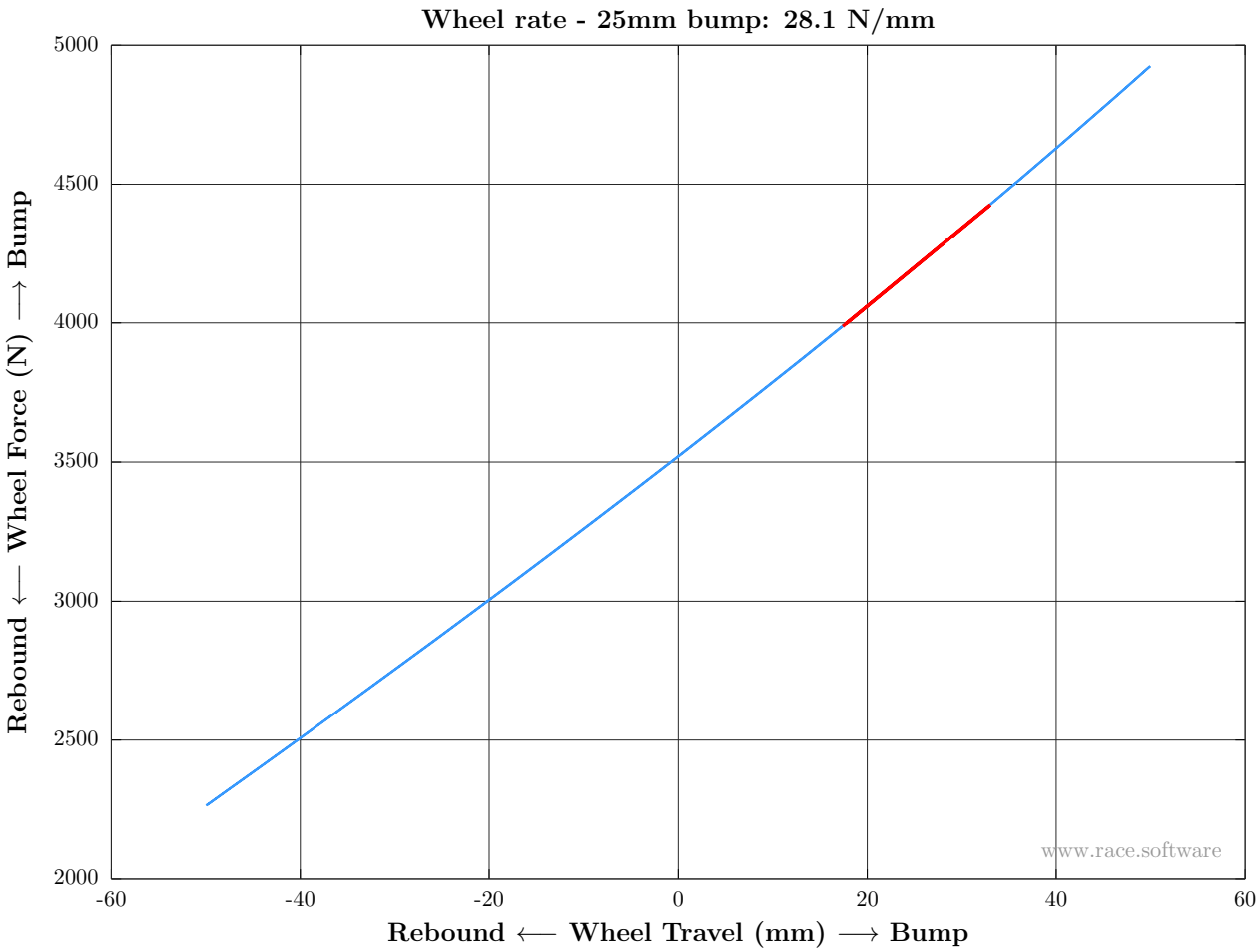

Figure 15: Vertical test: Wheel rate - 25mm bump

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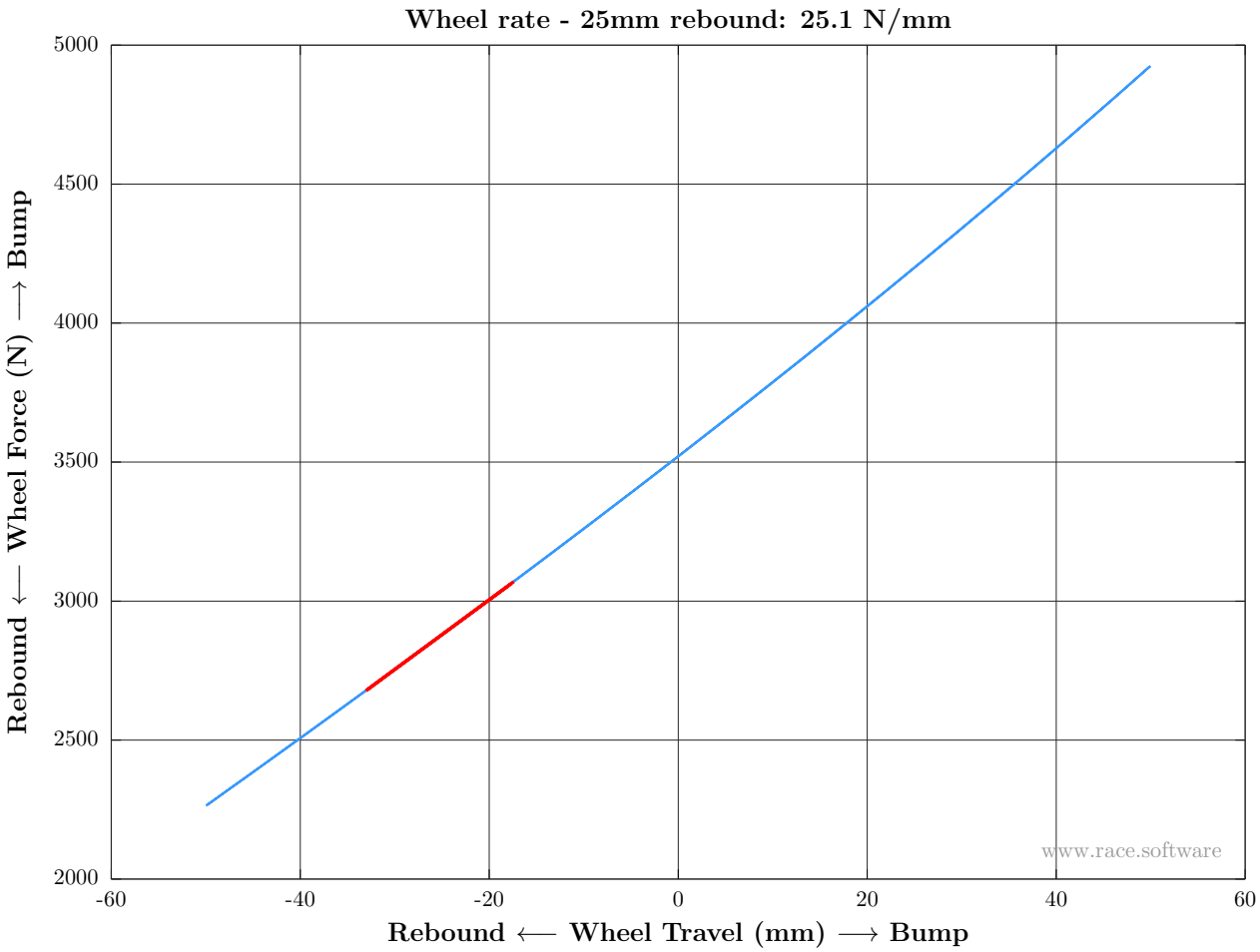

Figure 16: Vertical test: Wheel rate - 25mm rebound

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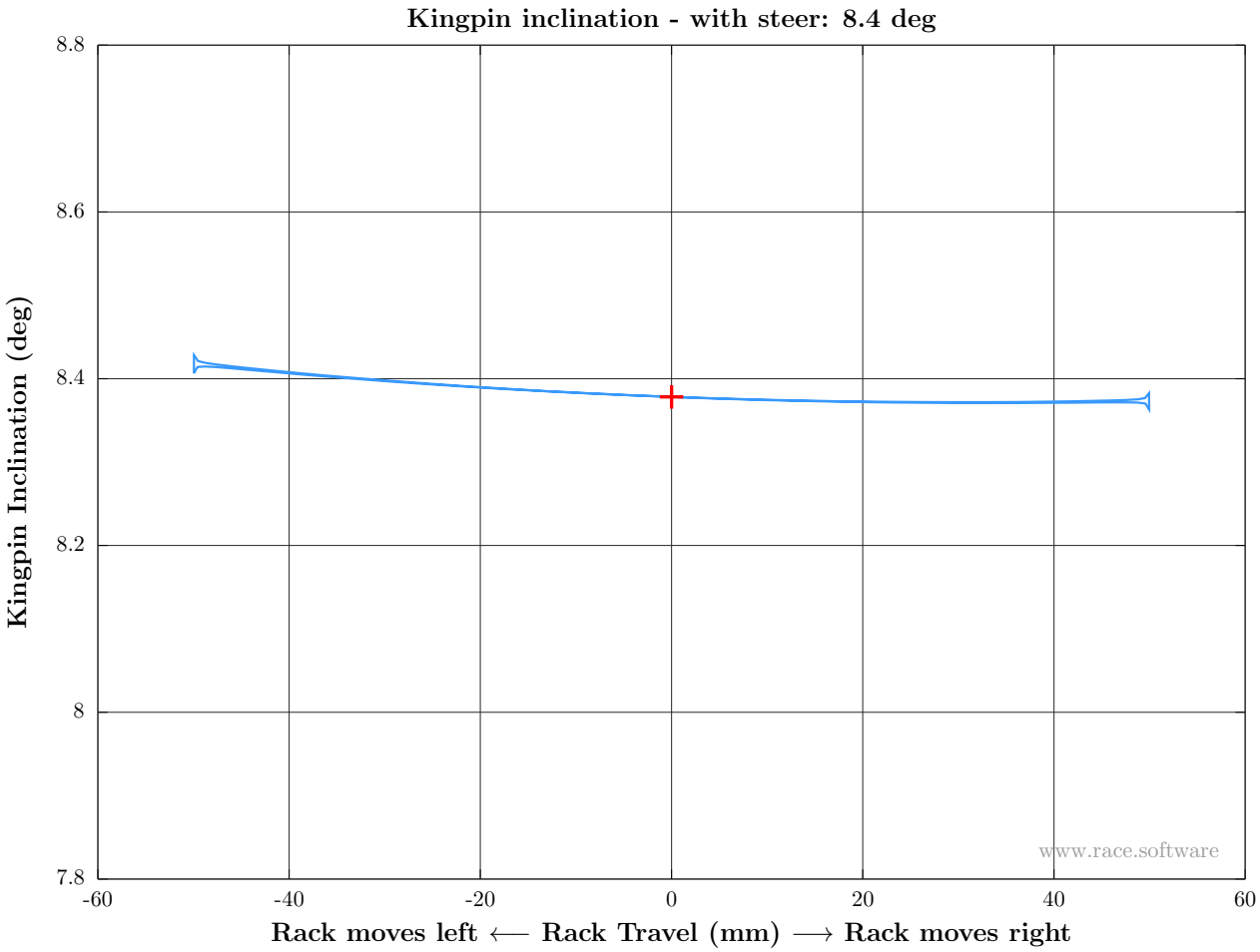

Figure 17: Steering test: Kingpin inclination - with steer

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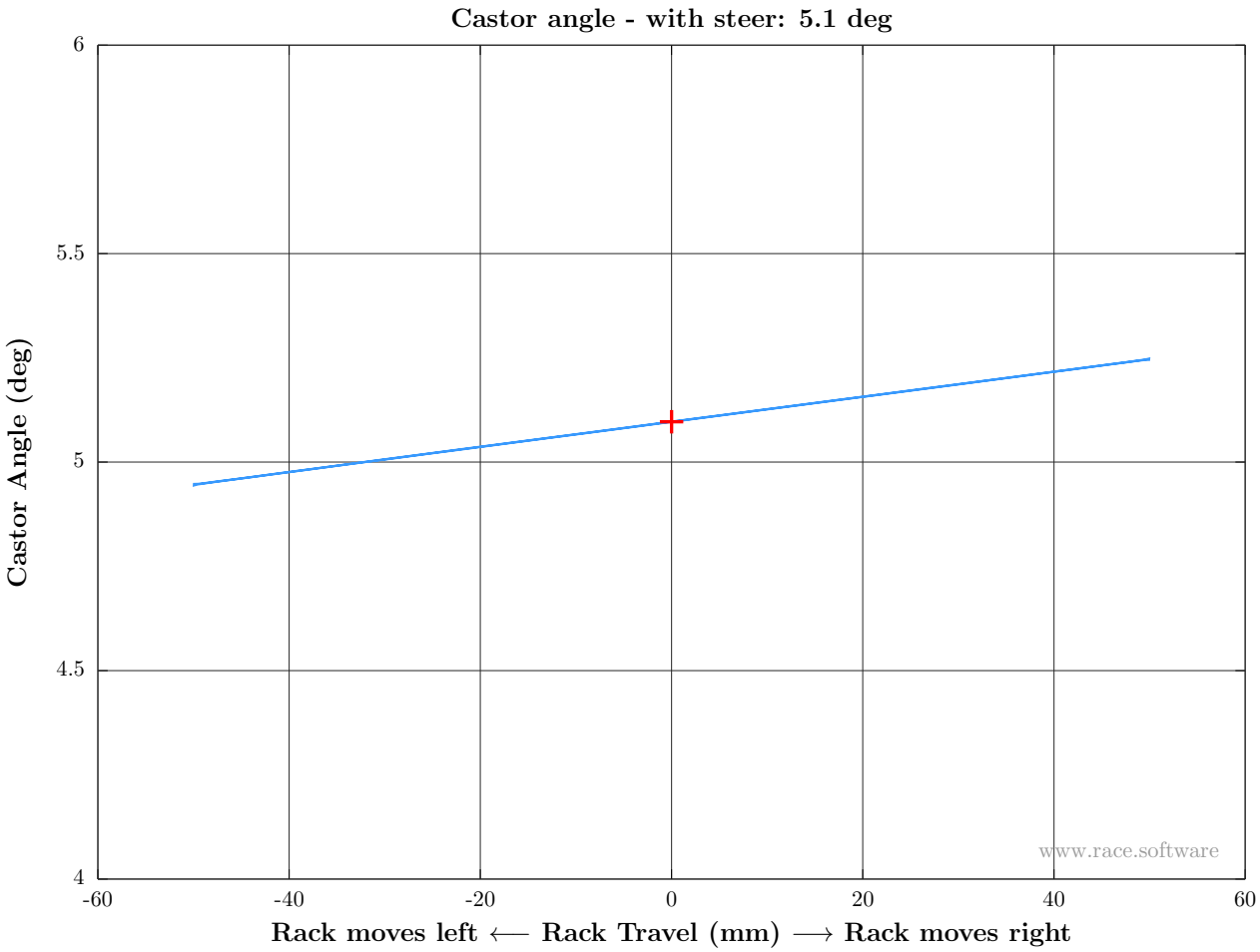

Figure 18: Steering test: Castor angle - with steer

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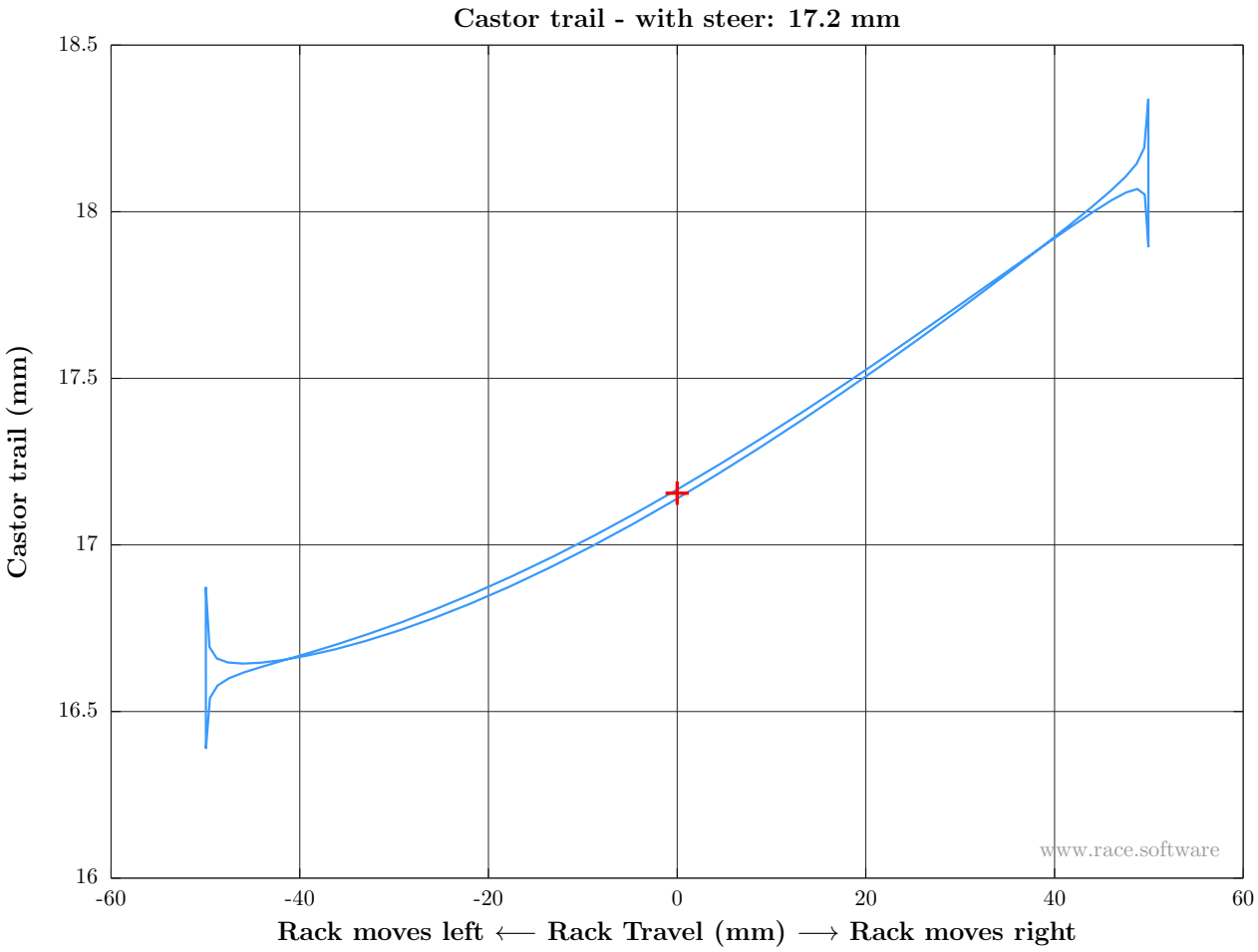

Figure 19: Steering test: Castor trail - with steer

⟸ **Back to Kinematics KPI Summary**

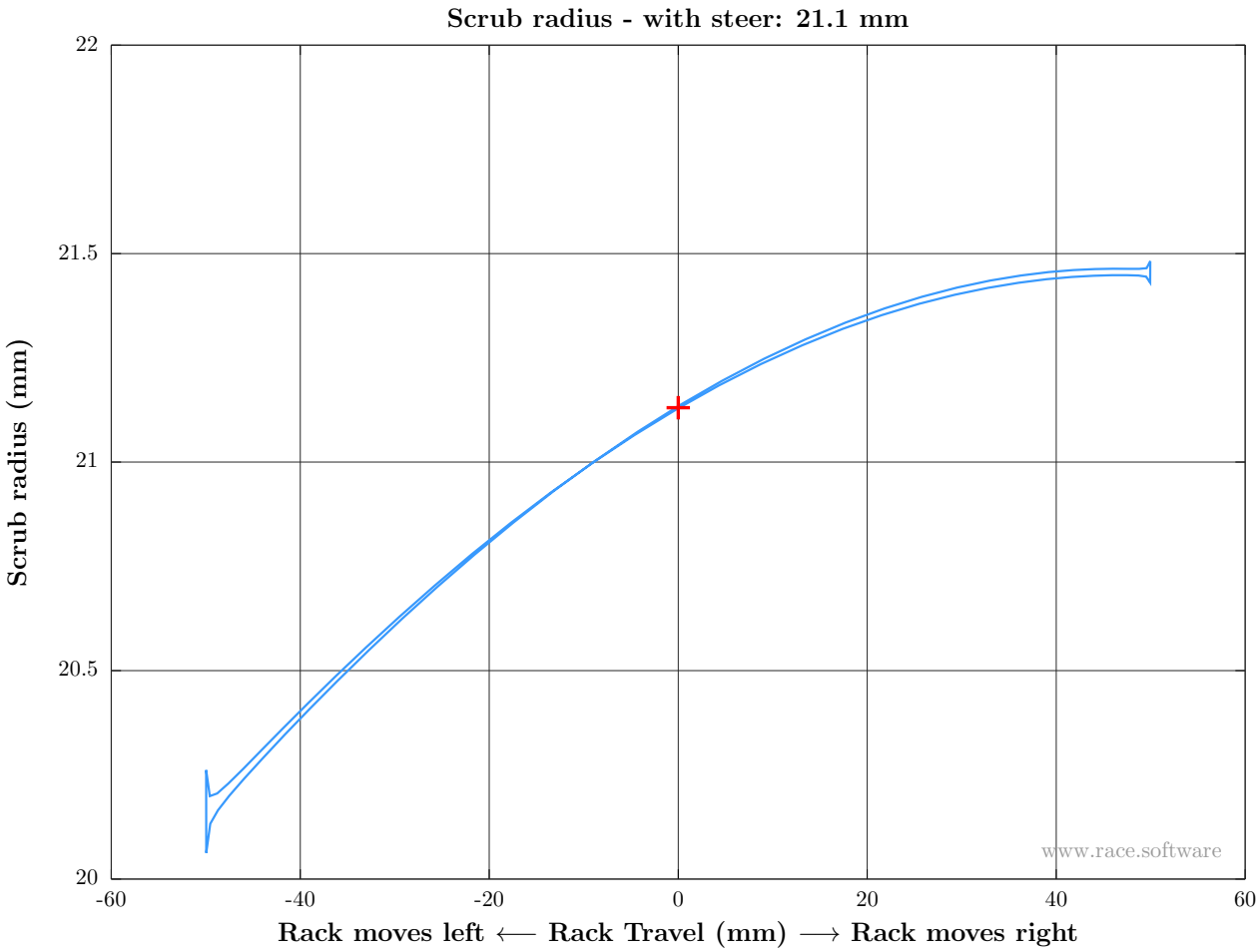

Figure 20: Steering test: Scrub radius - with steer

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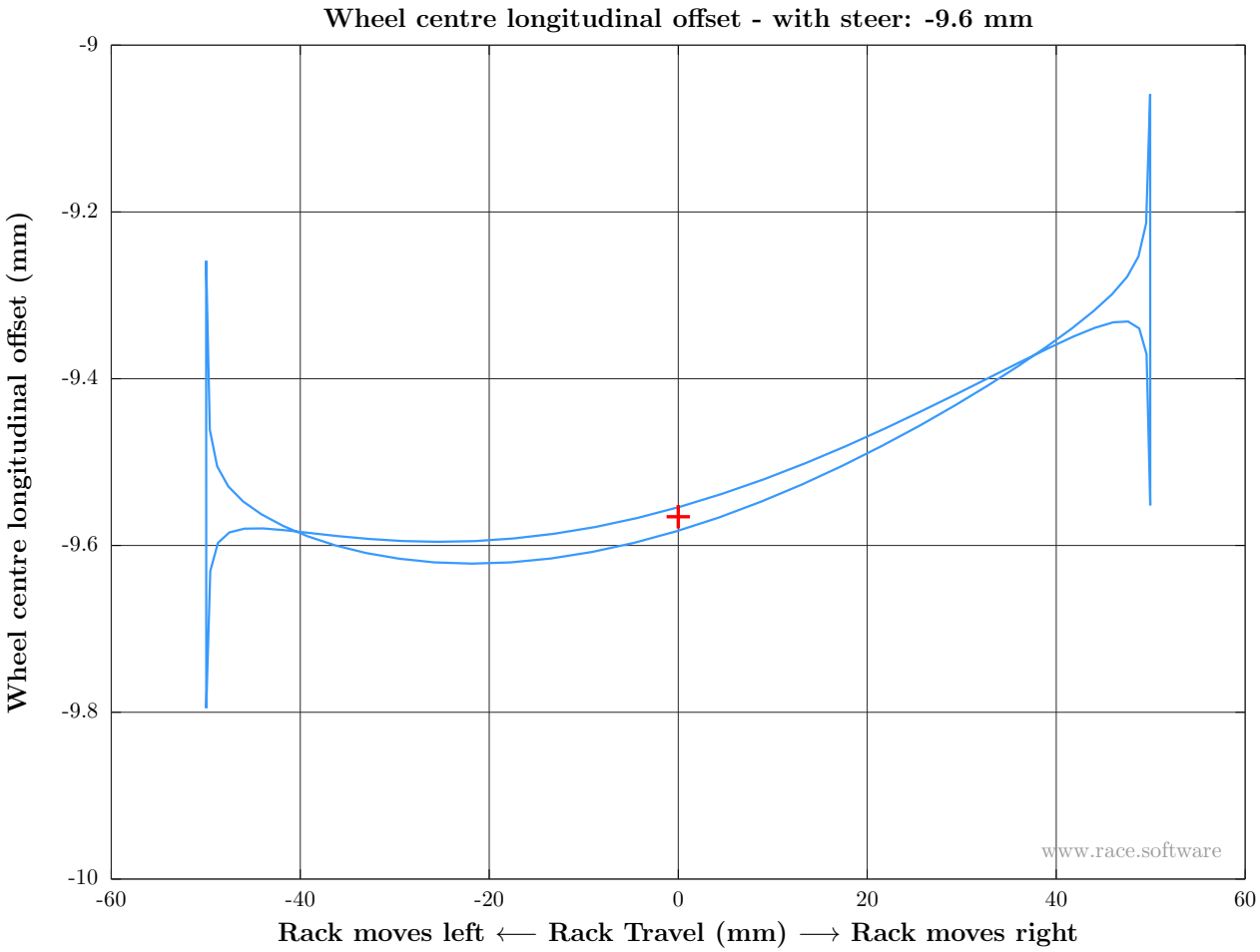

Figure 21: Steering test: Wheel centre longitudinal offset - with steer

⟸ **Back to Kinematics KPI Summary**

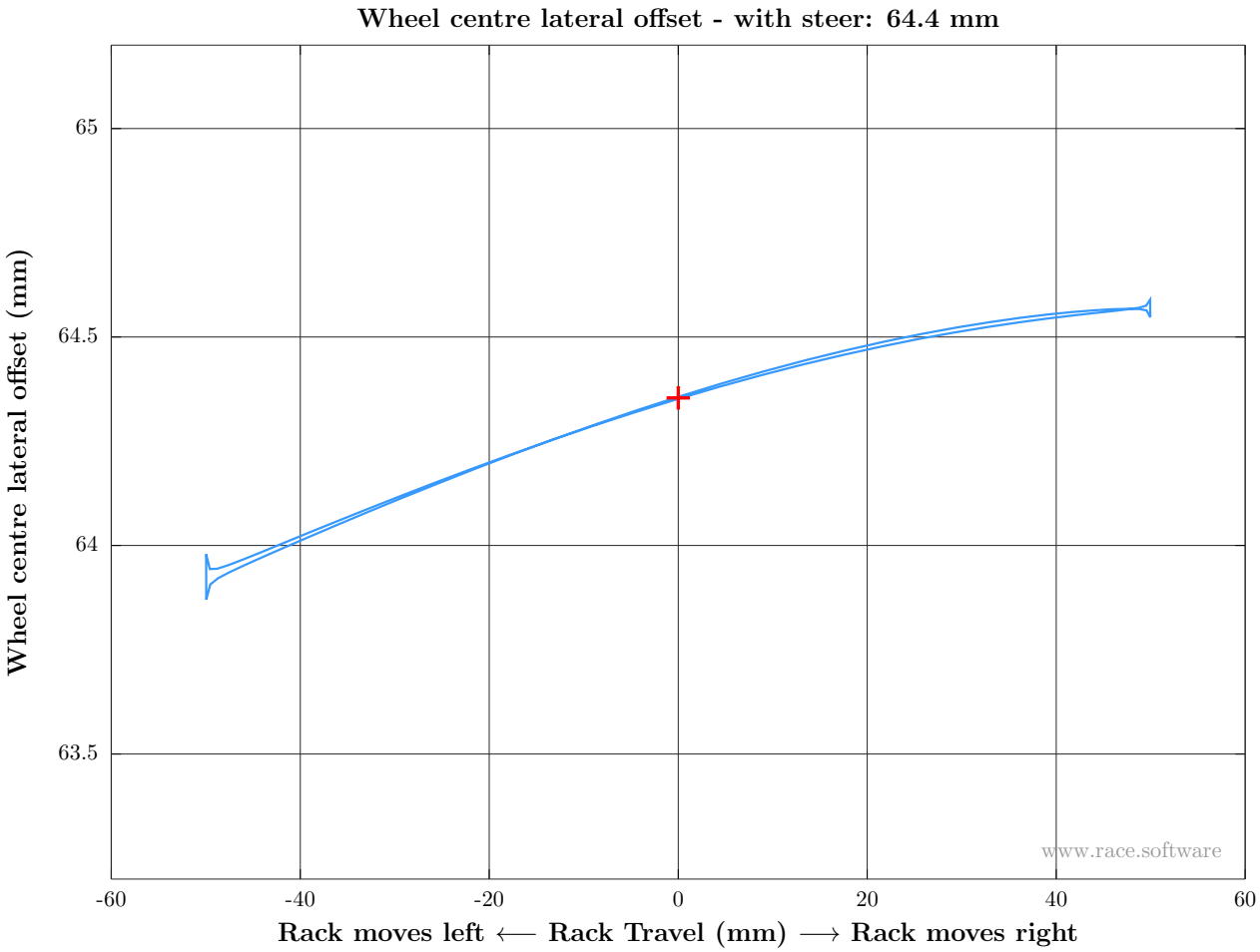

Figure 22: Steering test: Wheel centre lateral offset - with steer

⟸ **Back to Kinematics KPI Summary**

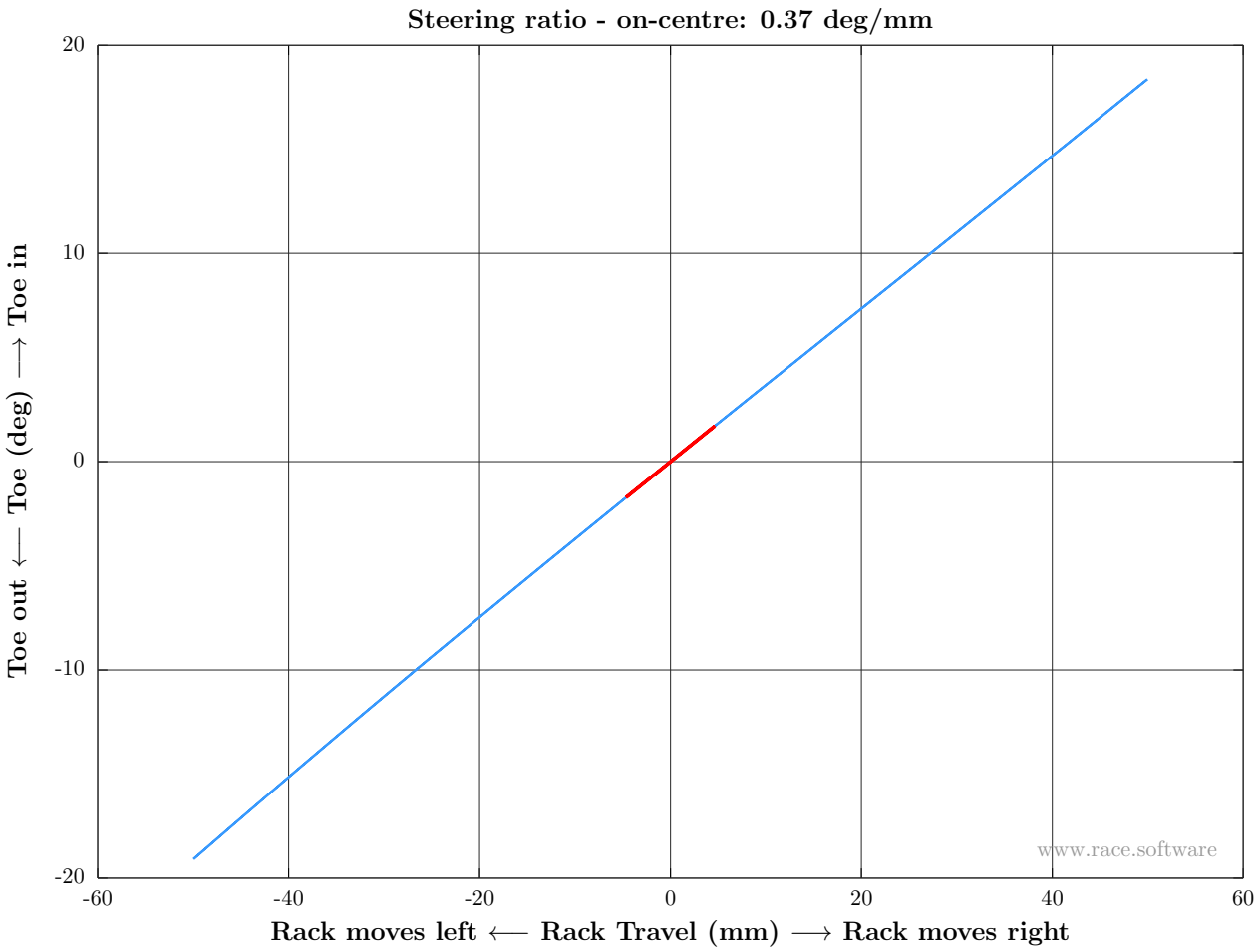

Figure 23: Steering test: Steering ratio - on-centre

⟸ **Back to Kinematics KPI Summary**

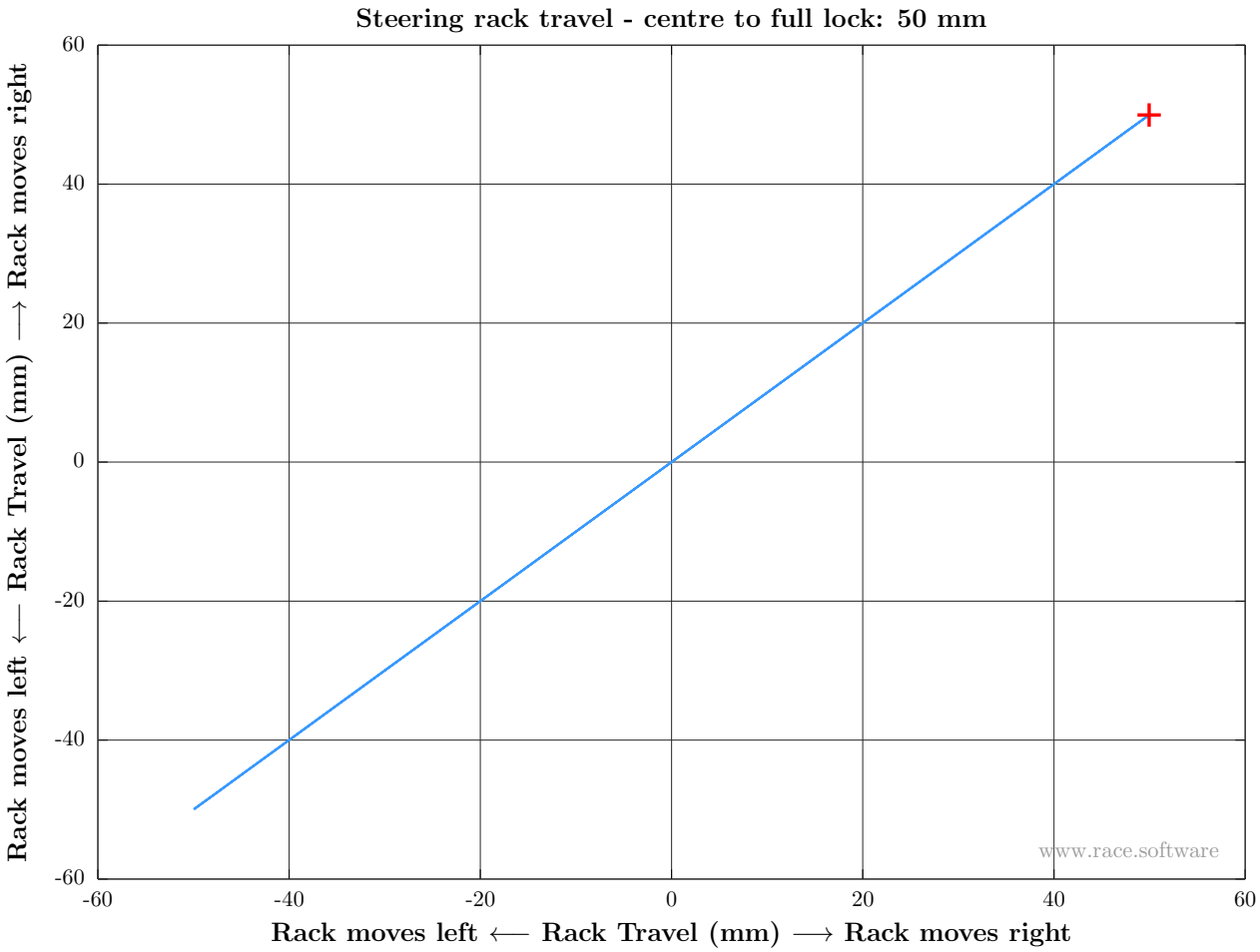

Figure 24: Steering test: Steering rack travel - centre to full lock

⟸ **Back to Kinematics KPI Summary**

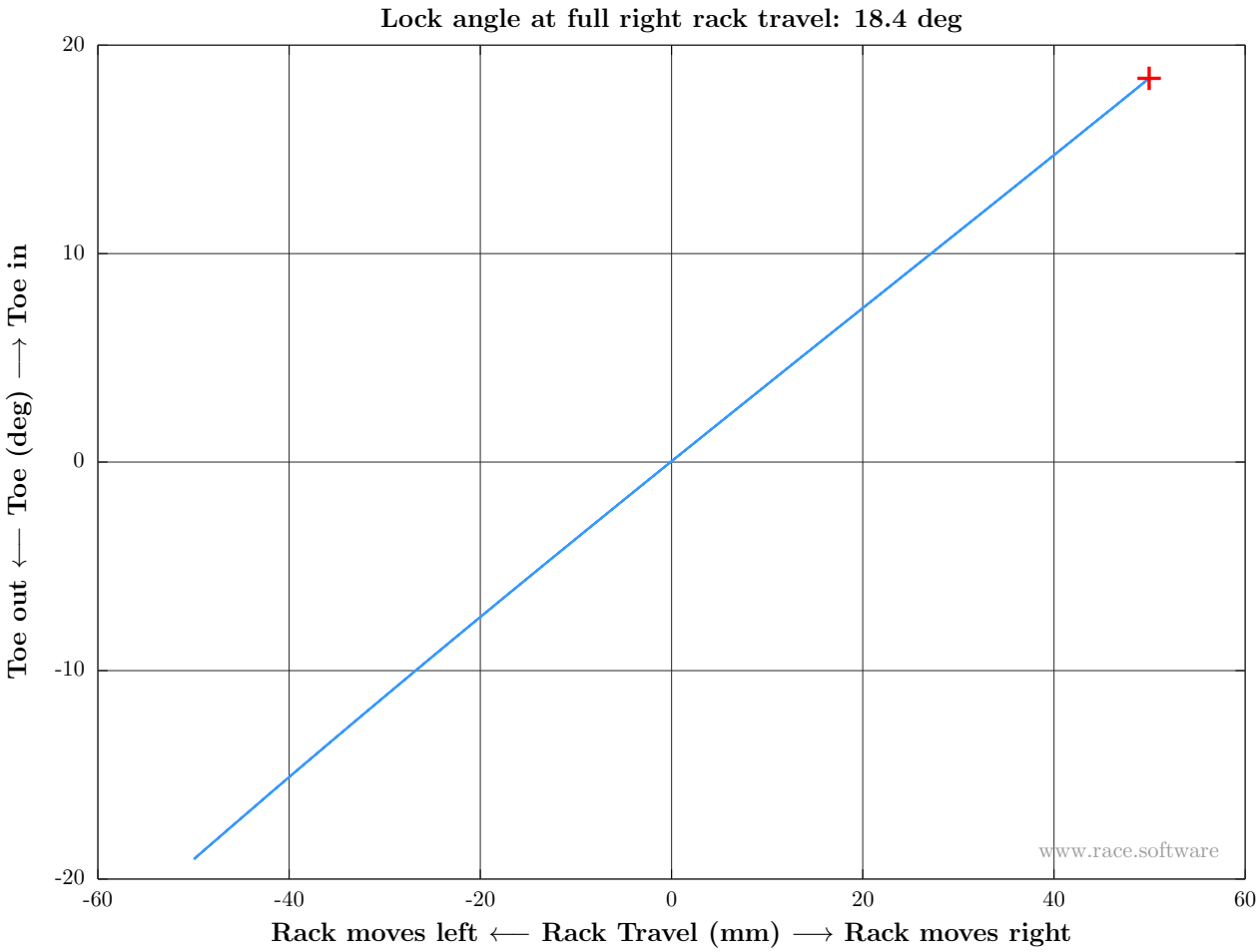

Figure 25: Steering test: Lock angle at full right rack travel

⟸ **Back to Kinematics KPI Summary**

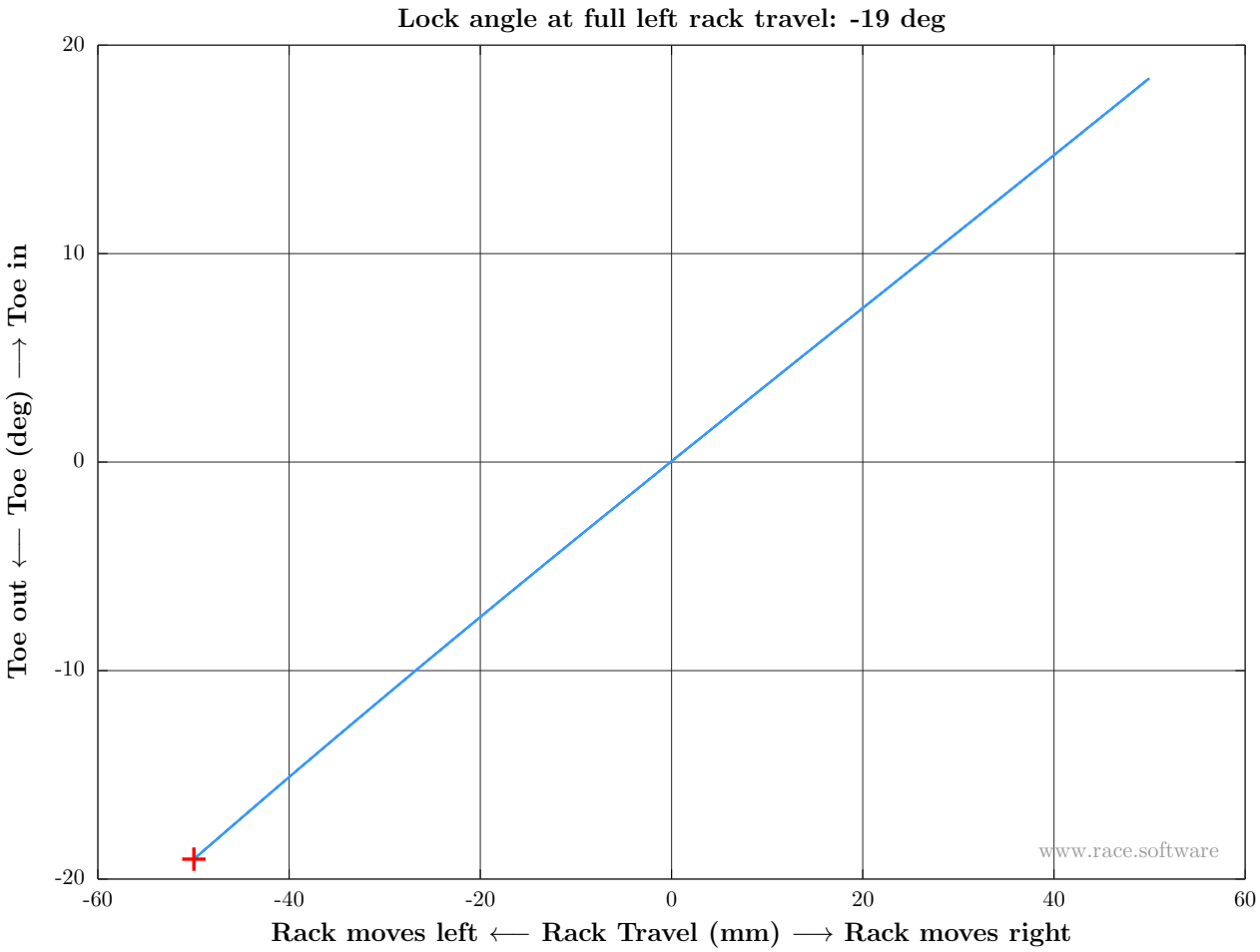

Figure 26: Steering test: Lock angle at full left rack travel

⟸ **Back to Kinematics KPI Summary**

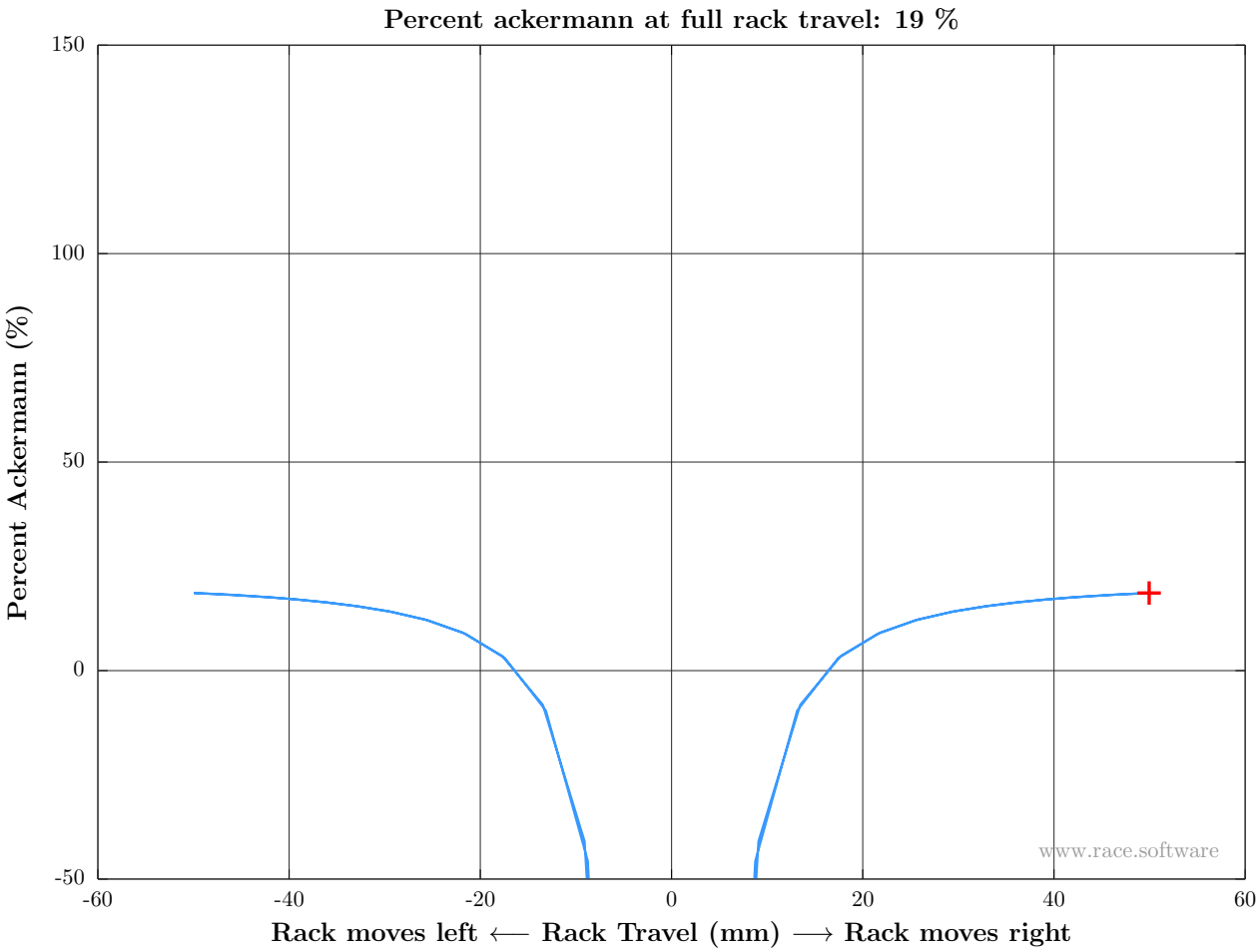

Figure 27: Steering test: Percent ackermann at full rack travel

⟸ **Back to Compliance KPI Summary**

Figure 28: Lateral test: Roll centre height - wheel load variation

⟸ Back to Compliance KPI Summary

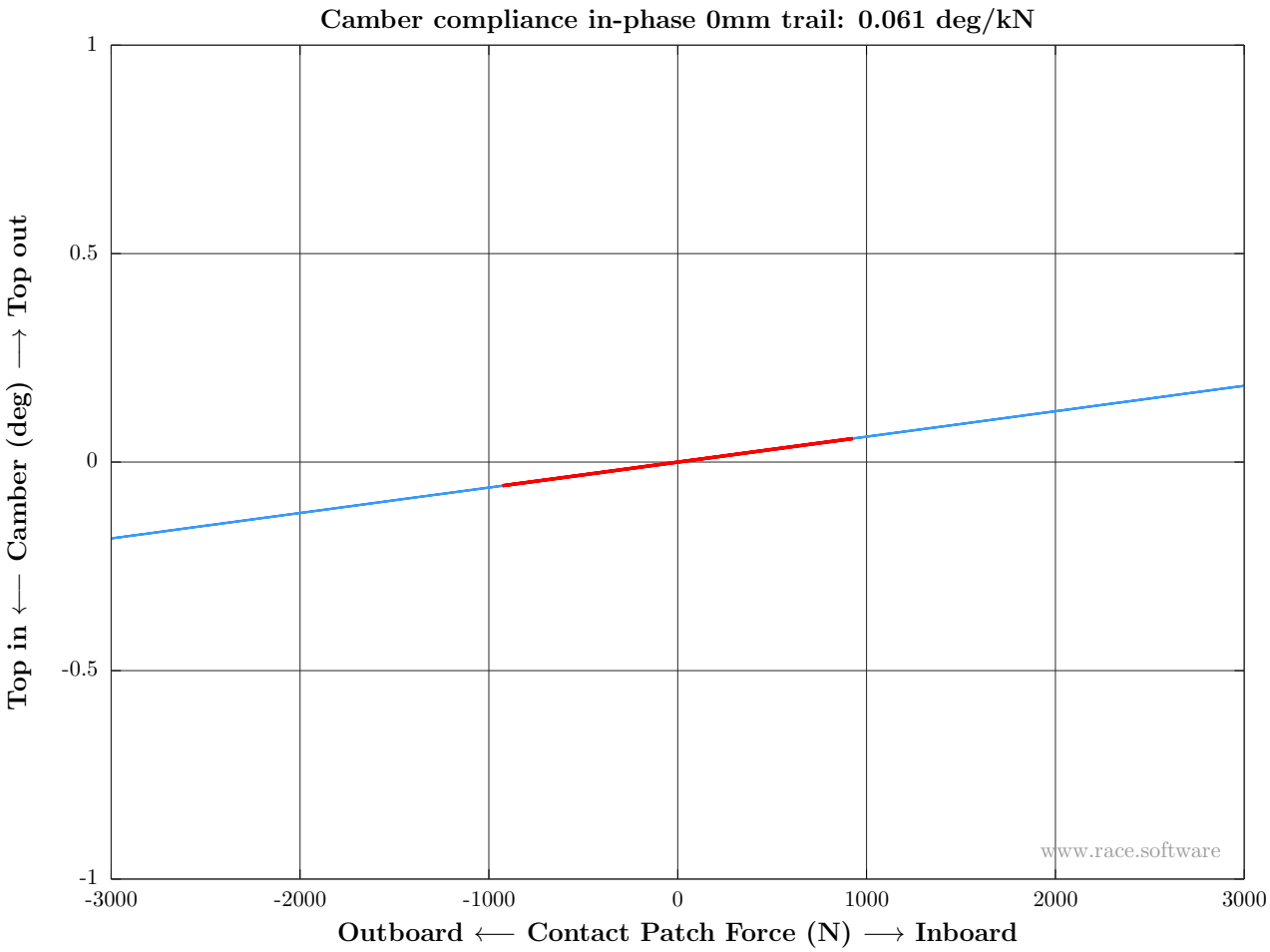

Figure 29: Lateral test: Camber compliance in-phase 0mm trail

⟸ Back to Compliance KPI Summary

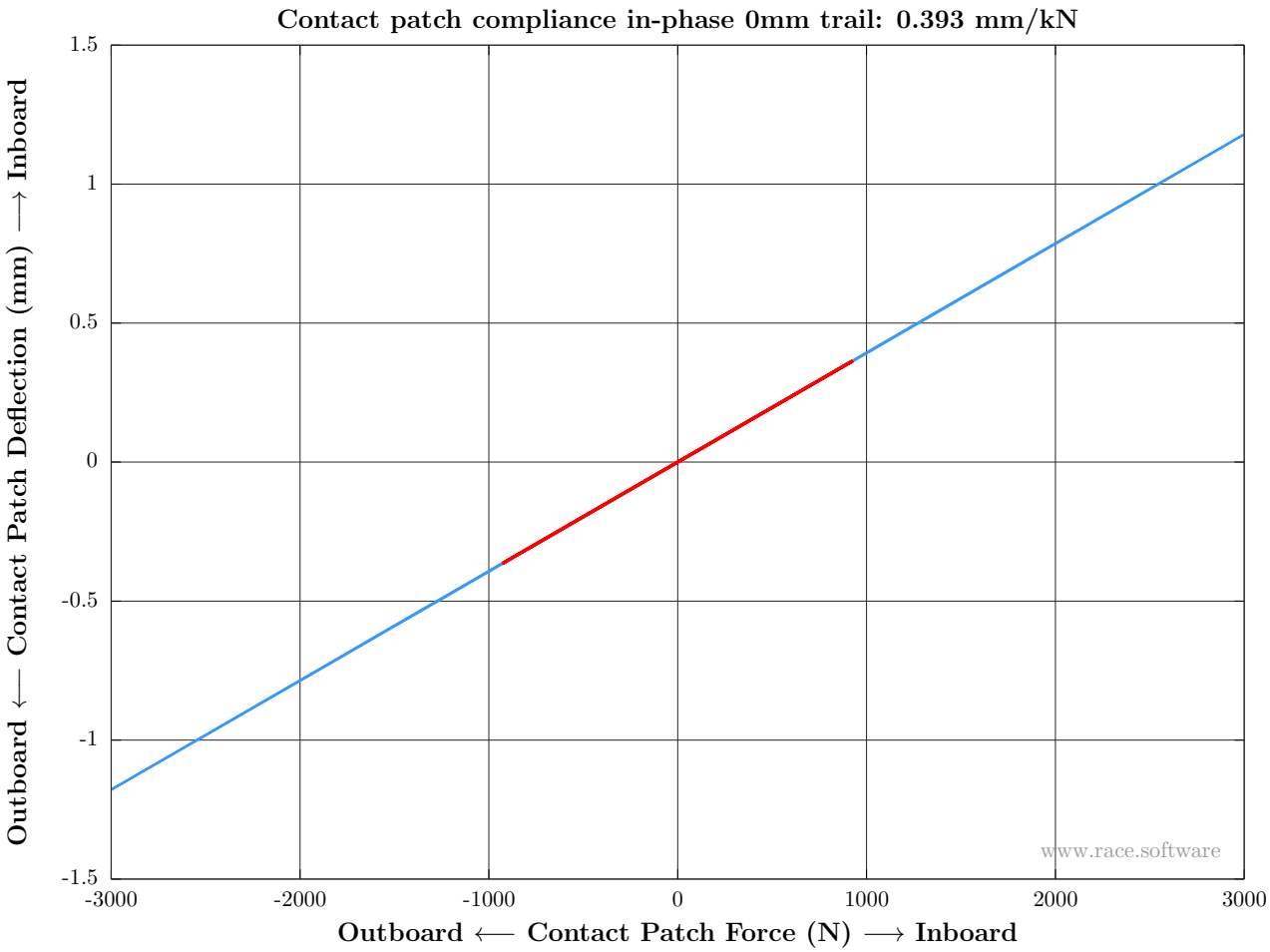

Figure 30: Lateral test: Contact patch compliance in-phase 0mm trail

⟸ **Back to Compliance KPI Summary**

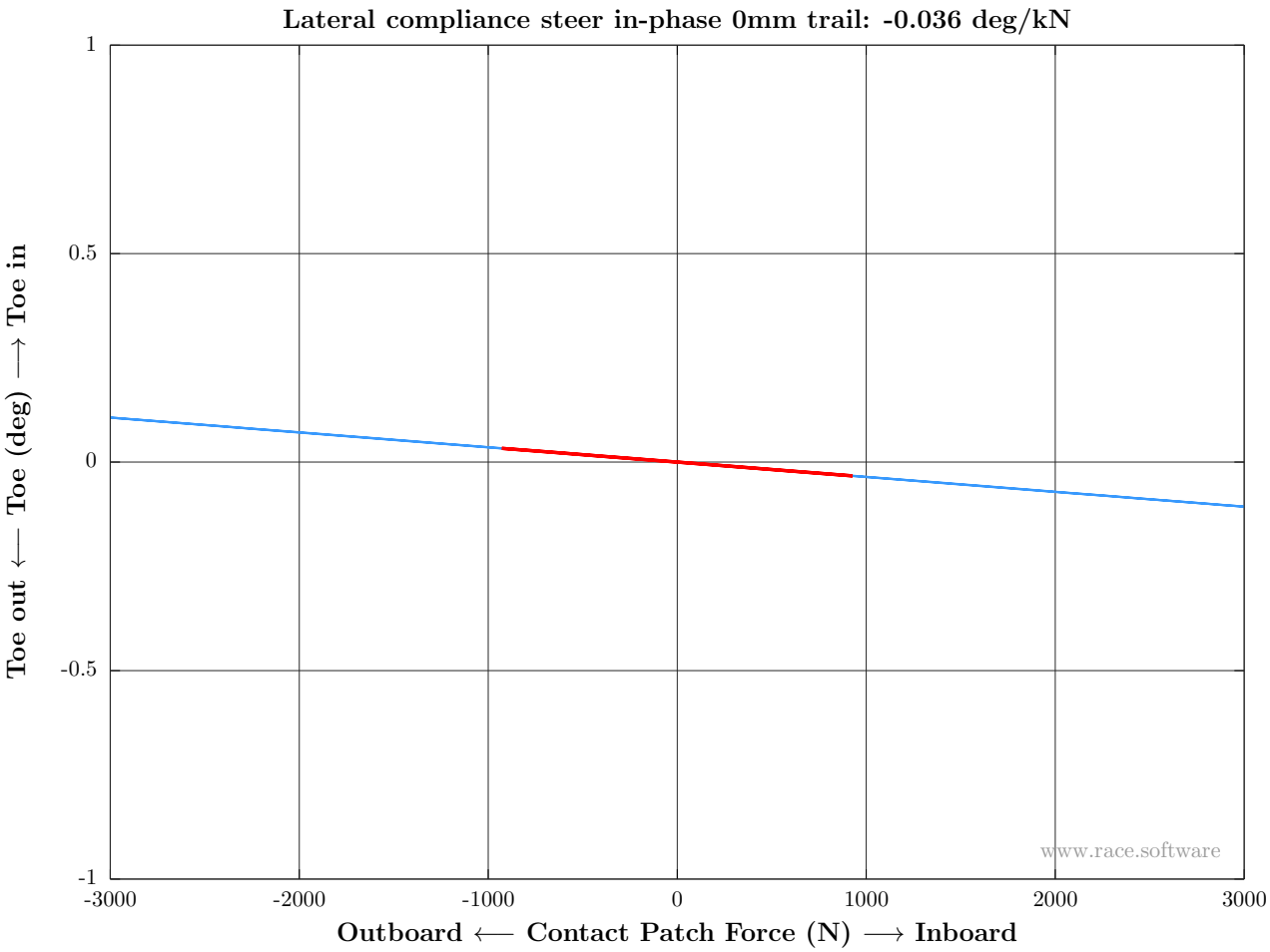

Figure 31: Lateral test: Lateral compliance steer in-phase 0mm trail

⟸ **Back to Compliance KPI Summary**

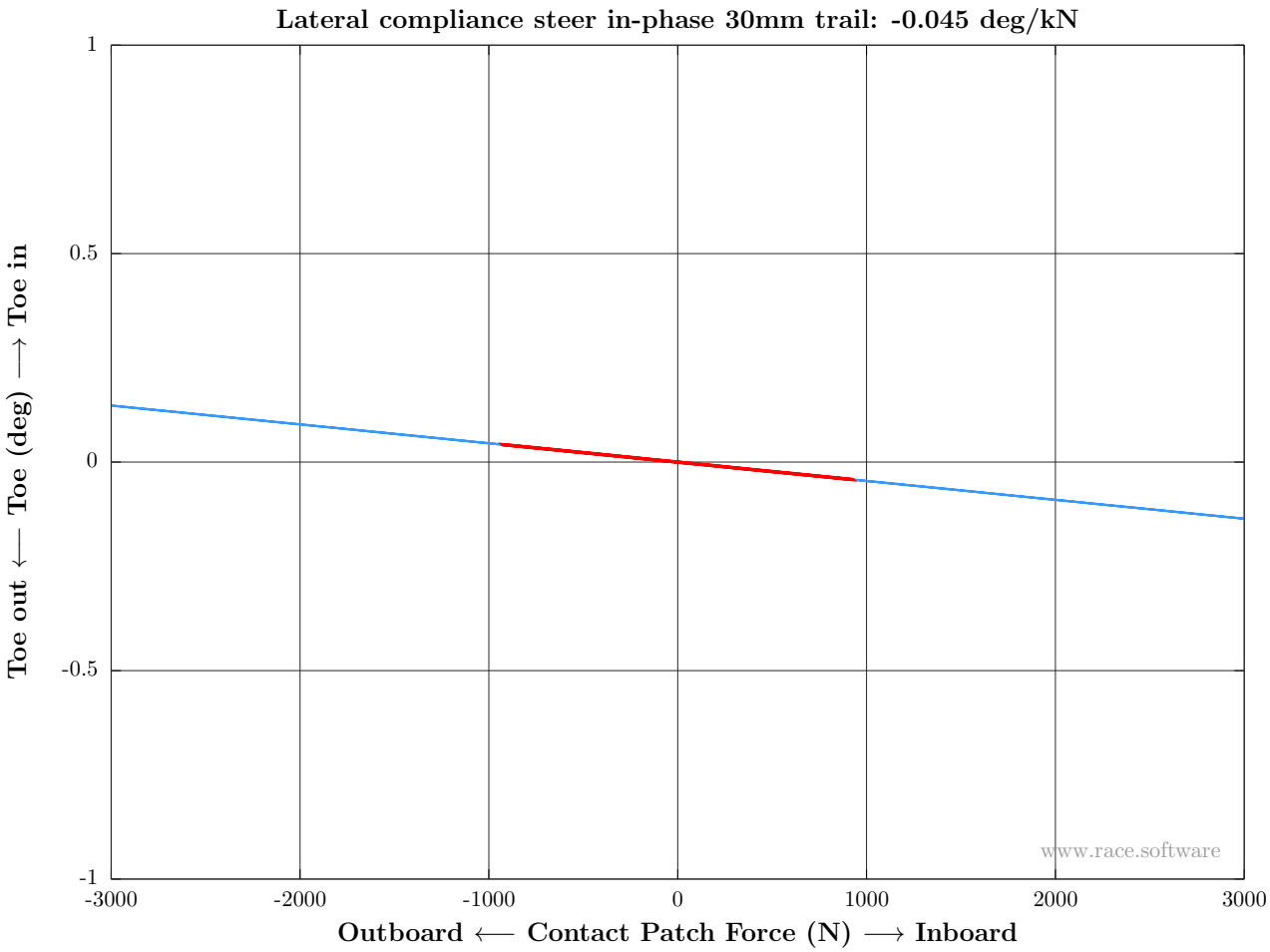

Figure 32: Lateral test: Lateral compliance steer in-phase 30mm trail

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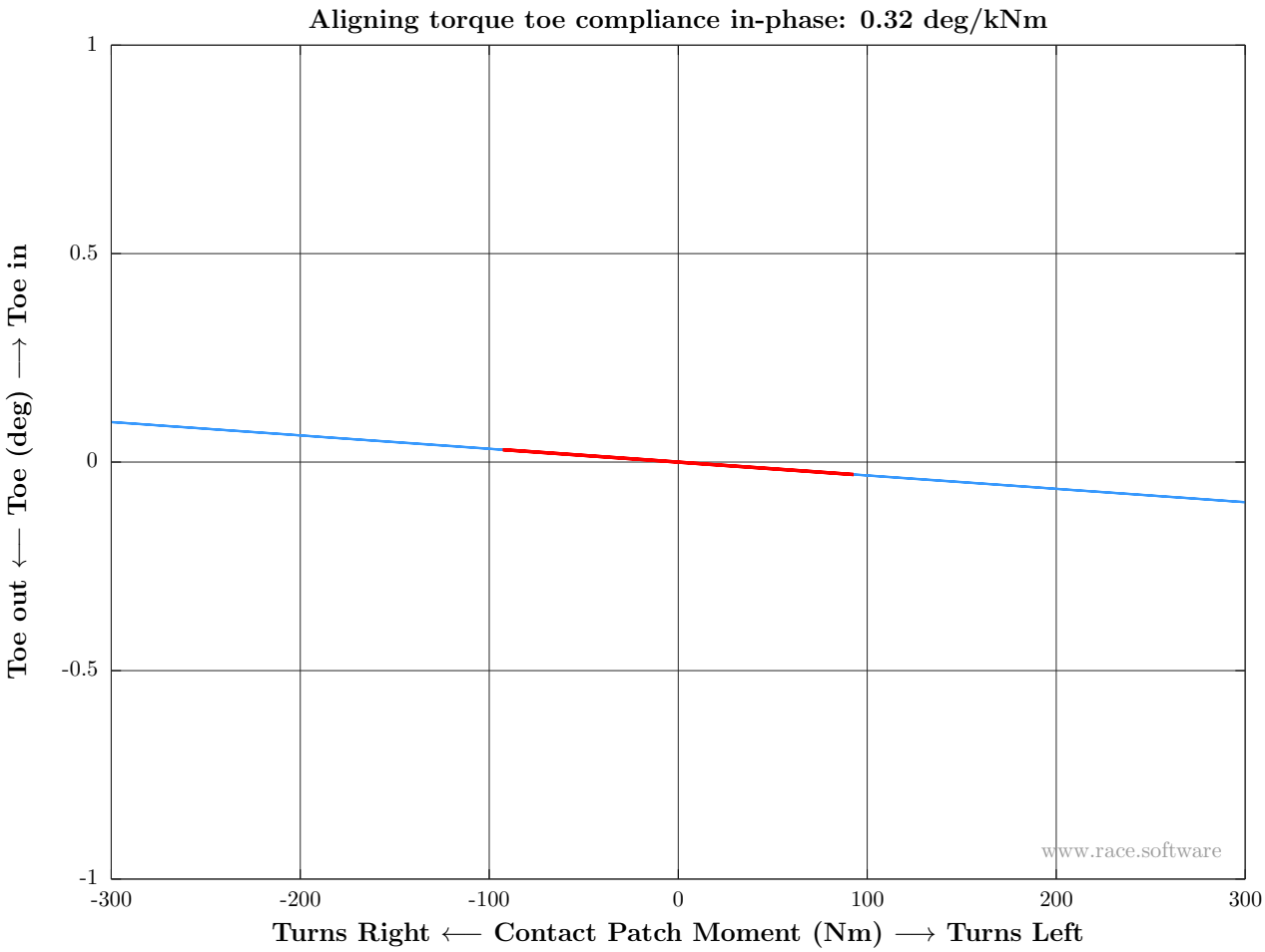

Figure 33: Aligning test: Aligning torque toe compliance in-phase

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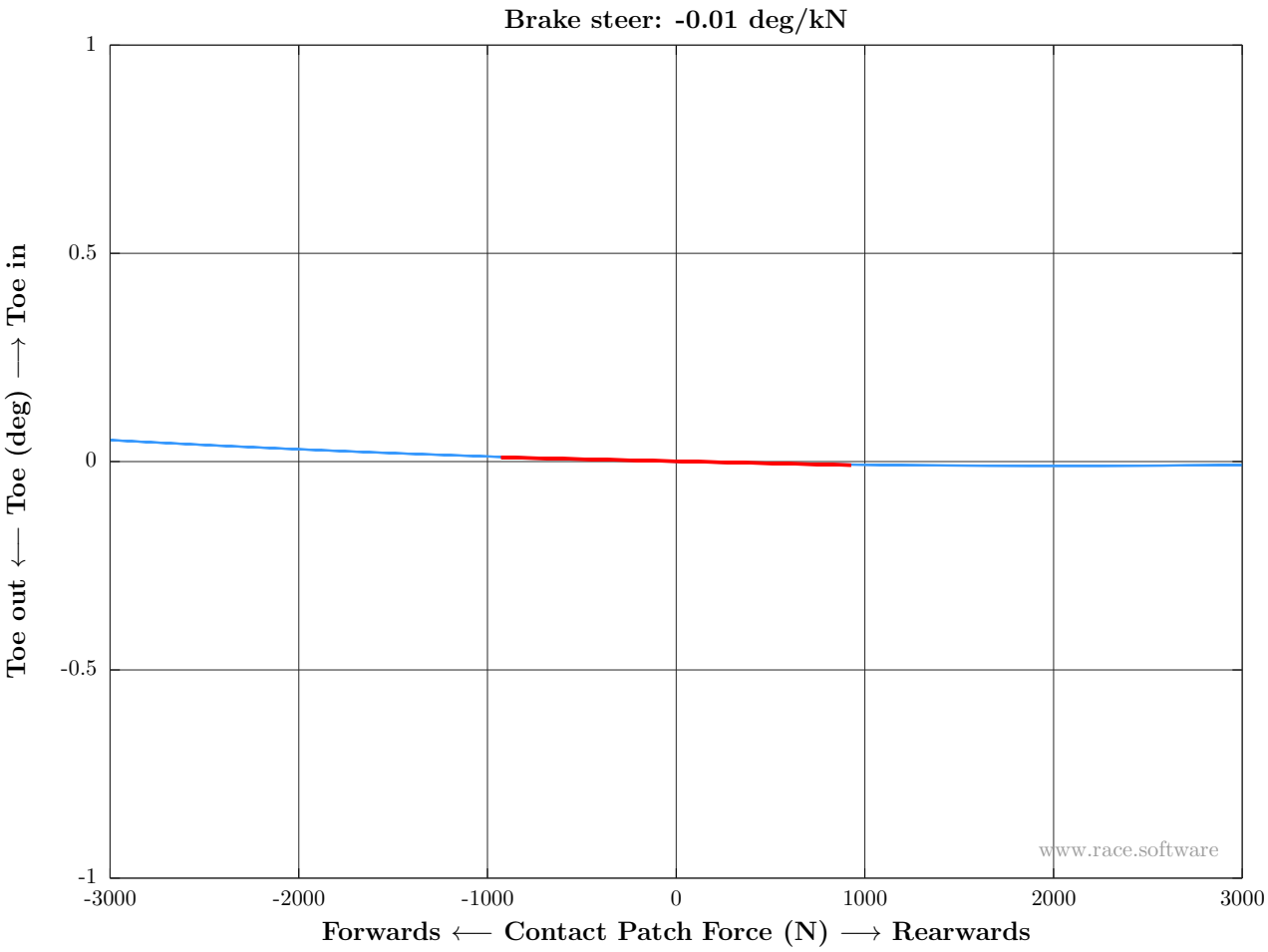

Figure 34: Braking test: Brake steer

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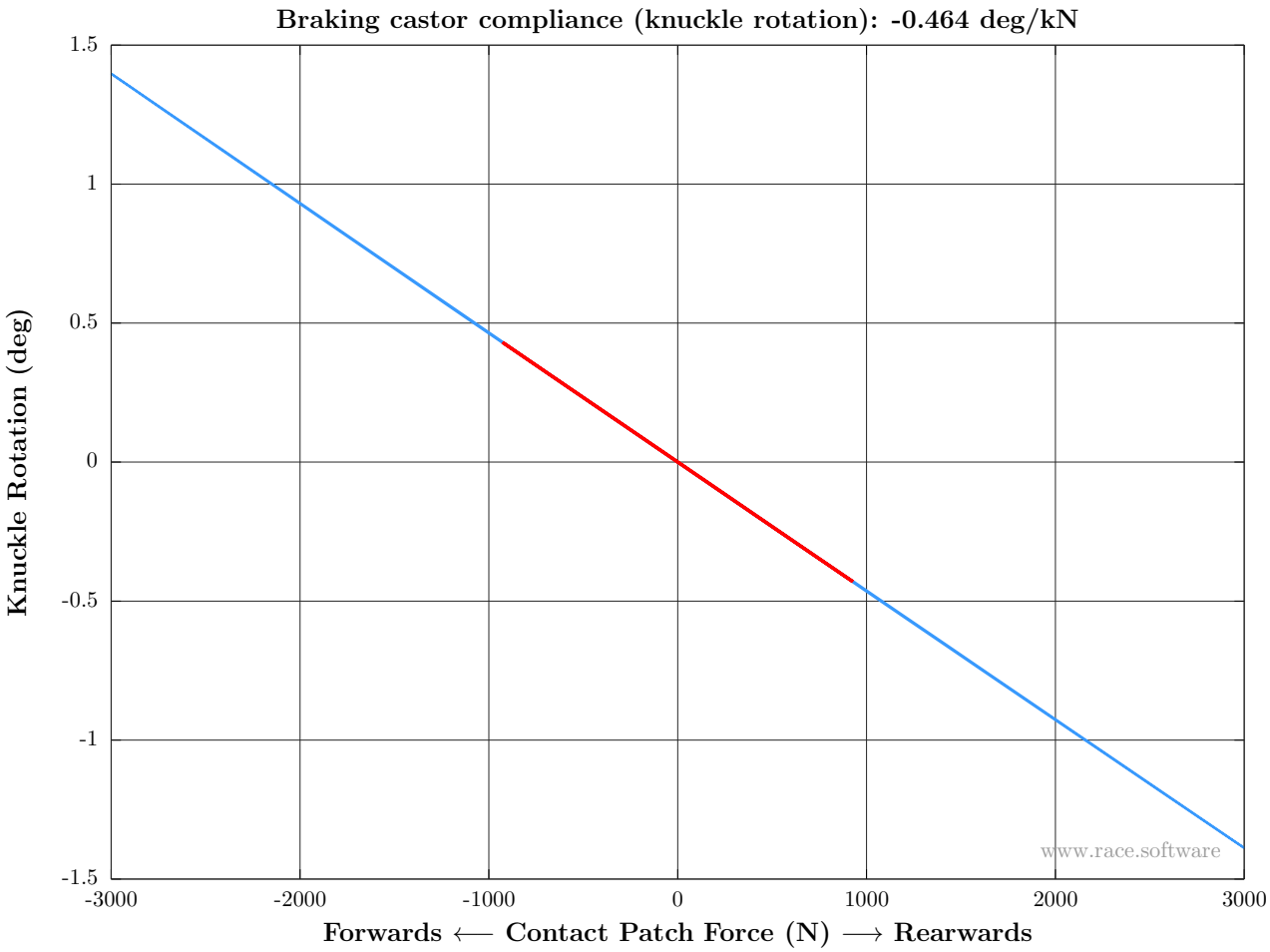

Figure 35: Braking test: Braking castor compliance (knuckle rotation)

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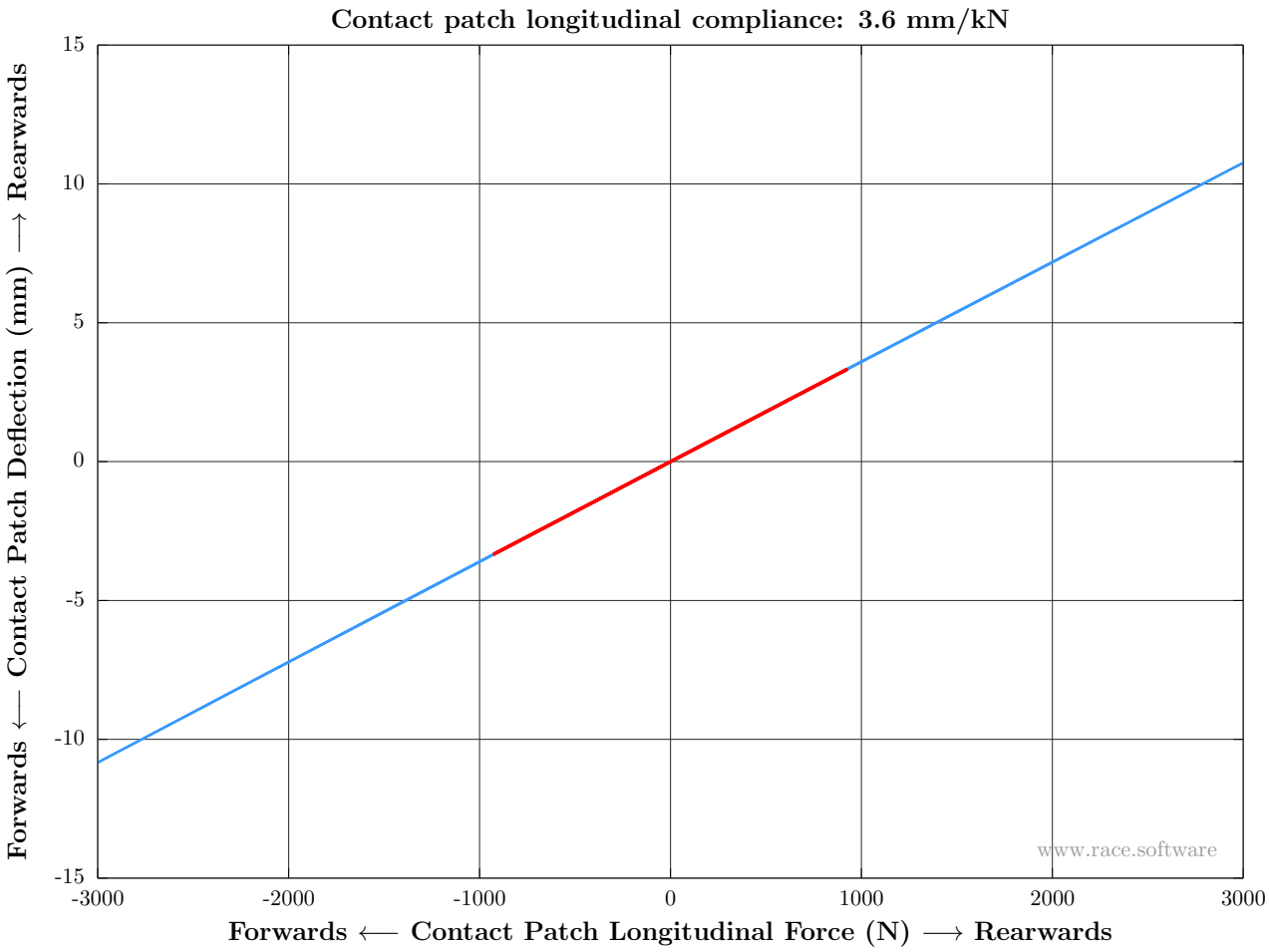

Figure 36: Braking test: Contact patch longitudinal compliance

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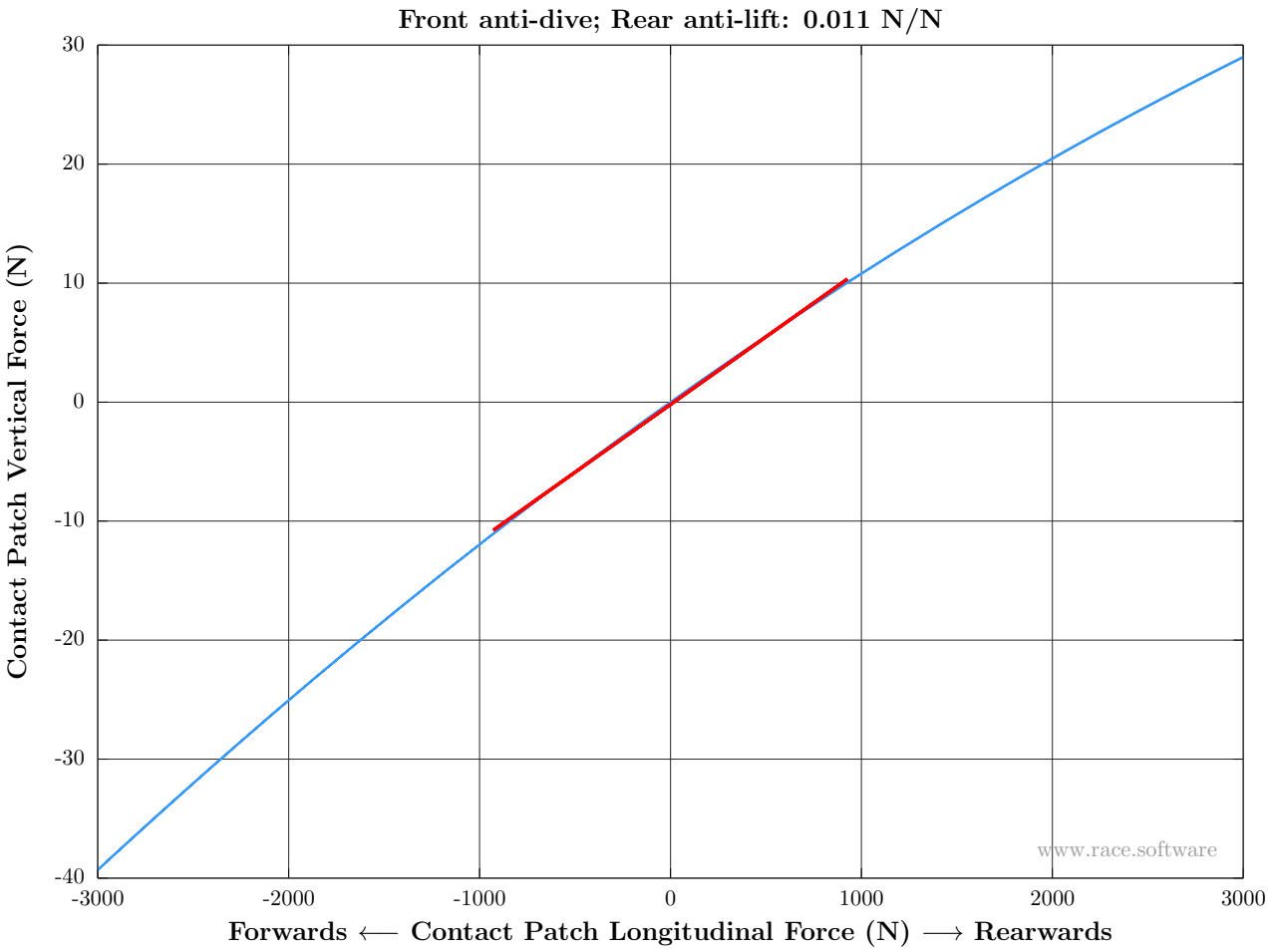

Figure 37: Braking test: Front anti-dive; Rear anti-lift

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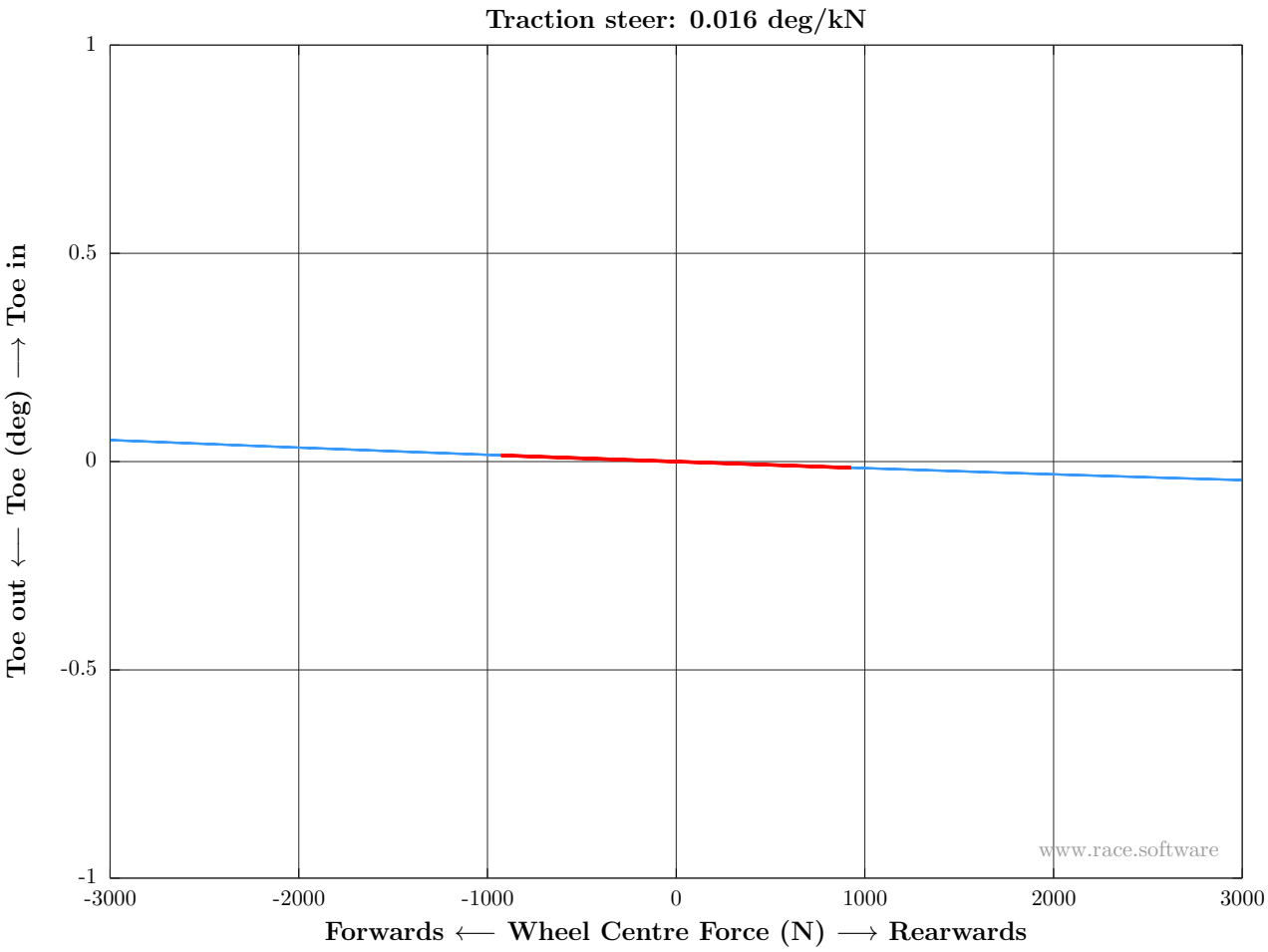

Figure 38: Traction test: Traction steer

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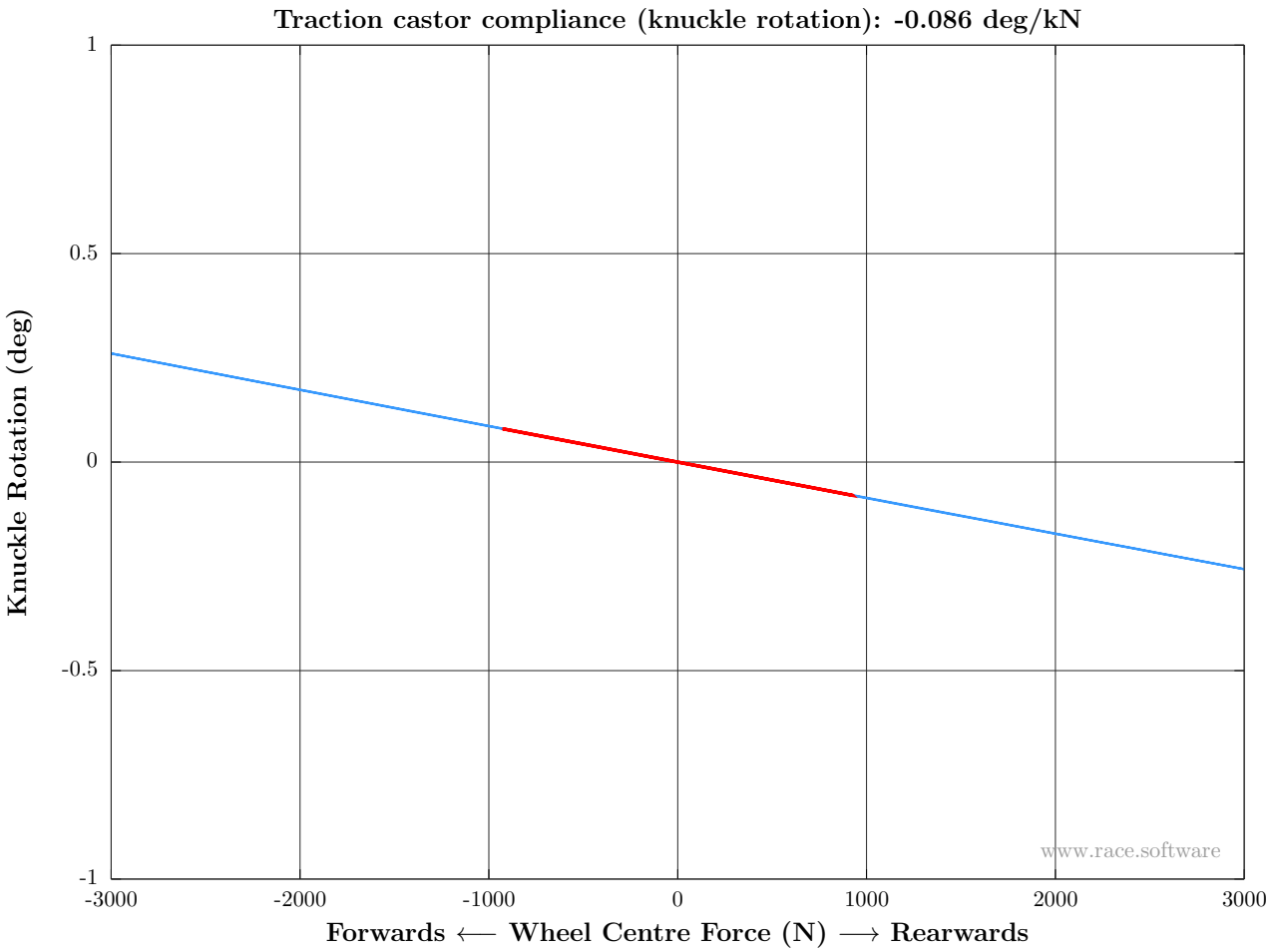

Figure 39: Traction test: Traction castor compliance (knuckle rotation)

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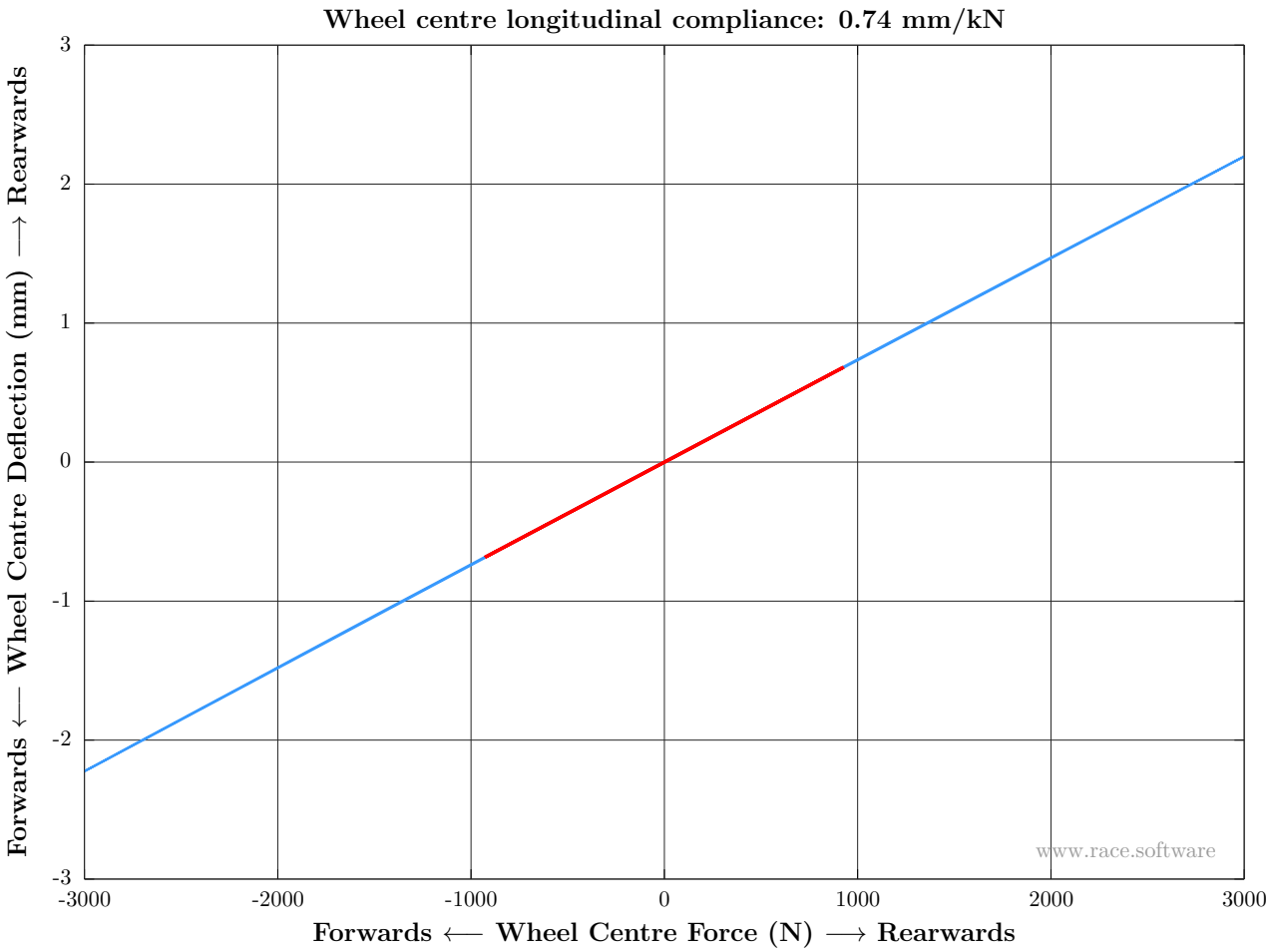

Figure 40: Traction test: Wheel centre longitudinal compliance

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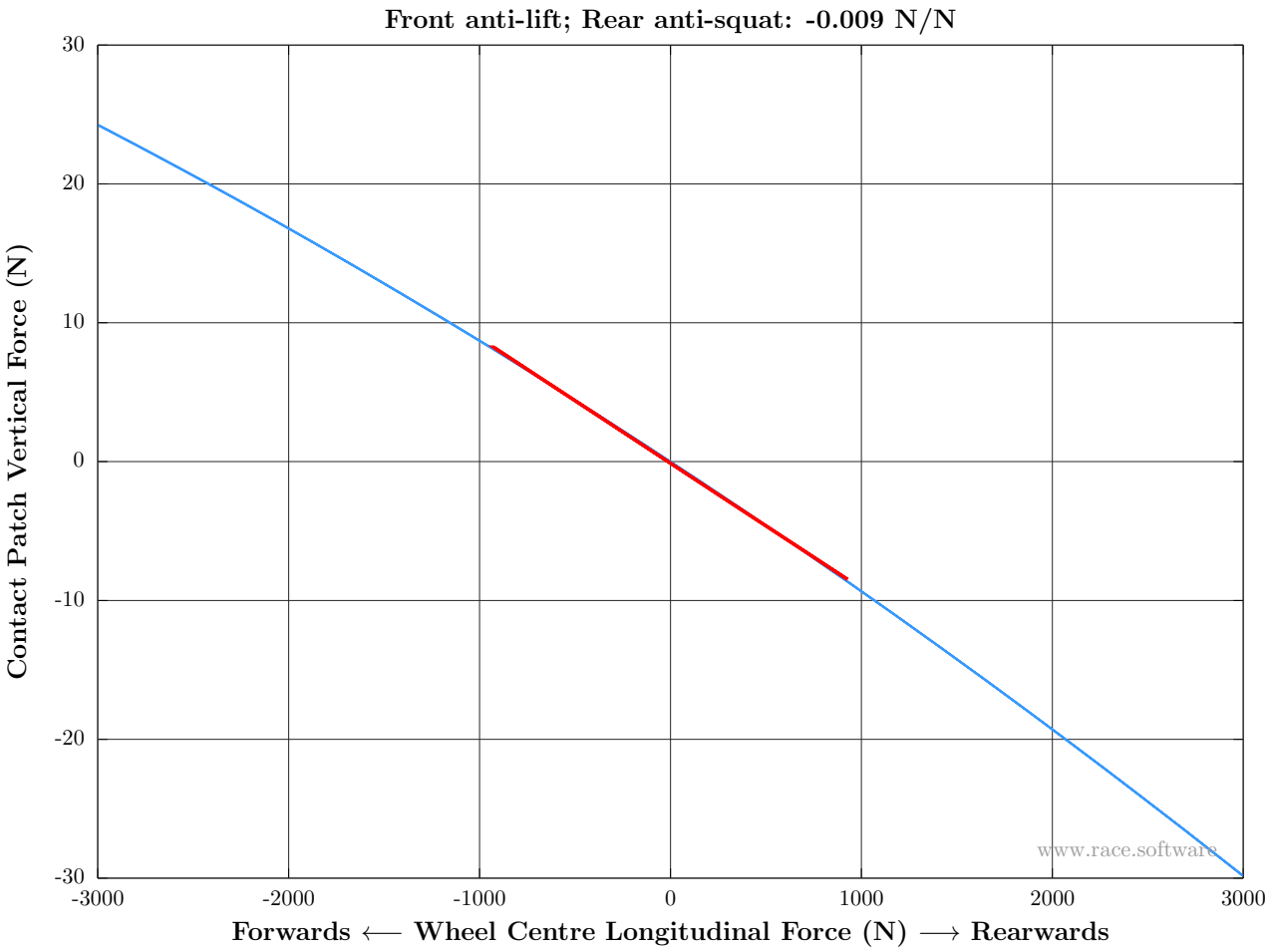

Figure 41: Traction test: Front anti-lift; Rear anti-squat

6 Key Performance Indicator Sign Conventions

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KPI	Unit	Positive metric sign meaning
BRAKING FORCE		
Brake steer	deg/kN	toe in under braking
Braking castor compliance (knuckle rotation)	deg/kN	castor angle increase under braking
Contact patch longitudinal compliance	mm/kN	rearward contact patch deflection under braking
Front anti-dive; Rear anti-lift	N/N	anti-dive (front axle); pro-lift (rear axle)
LATERAL FORCE		
Roll centre height - wheel load variation	N/N	roll centre above ground
Camber compliance in-phase 0mm trail	deg/kN	top of wheel outboard with lateral force
Contact patch compliance in-phase 0mm trail	mm/kN	contact patch deflection inboard
Lateral compliance steer in-phase 0mm trail	deg/kN	toe in with lateral force
STATIC GEOMETRY		
Static camber	deg	top of wheel outboard
Static toe	deg	front of wheel inboard (toe in)
STEERING INPUT		
Kingpin inclination - with steer	deg	top of axis is inboard
Castor angle - with steer	deg	top of axis is rearwards
Castor trail - with steer	mm	kingpin ground intersect forward of whl centre
Scrub radius - with steer	mm	kingpin ground intersect inboard of whl centre
Wheel centre longitudinal offset - with steer	mm	kingpin axis is rearwards of wheel centre
Wheel centre lateral offset - with steer	mm	kingpin axis is inboard of wheel centre
Lock angle at full right rack travel	deg	Wheel is steering to the right
Lock angle at full left rack travel	deg	Wheel is steering to the right
Percent ackermann at full rack travel	%	Pro-Ackermann (100% is perfect ackermann)
TRACTION FORCE		
Traction steer	deg/kN	toe in under acceleration
Traction castor compliance (knuckle rotation)	deg/kN	castor angle increase under traction
Wheel centre longitudinal compliance	mm/kN	rearward wheel centre deflection for an impact
Front anti-lift; Rear anti-squat	N/N	anti-lift (front axle); pro-squat (rear axle)
TYRE ALIGNING TORQUE		
Aligning torque toe compliance in-phase	deg/kNm	toe change in the direction of the moment
VERTICAL MOTION		
Bump camber	deg/m	top of wheel outboard with bump travel
Bump steer - on centre	deg/m	toe in with bump travel
Bump castor (knuckle rotation)	deg/m	top of wheel rearward in bump
Kinematic wheel centre recession	mm/m	rearward wheel travel in bump
Contact patch lateral migration	mm/m	contact patch inboard migration in bump