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2007

Document Version:
Publisher's PDF, also known as Version of record

Link to publication

Citation for published version (APA):
Svendenius, J. (2007). *Validation of the Brush Model towards VTI-measurement data recorded at Hällered 2005*. (Technical Reports TFRT-7616). Department of Automatic Control, Lund Institute of Technology, Lund University.

Total number of authors:
1

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ISSN 0280–5316
ISRN LUTFD2/TFRT--7616--SE

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January 2007

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Document name
INTERNAL REPORT

Date of issue
January 2007

Document Number
ISRN LUTFD2/TFRT--7616--SE

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Title and subtitle
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Abstract

The report shows a validation of the brush tire-model towards measurement data performed in the RFE-project within the IVSS-framework. The data is recorded by VTI at Volvos test track, Hällered. The winter tire, Continental ContiWinterContact TS810 215/55R16 and the summer tire, Continental ContiSportContact 225/45R17 91W are tested longitudinally and laterally at different conditions. A study of how the braking stiffness, the cornering stiffness and the friction varies with the varying conditions is performed.

Key words
Tire Models, Measurement Data, Hällered, Brush Model

Classification system and/or index terms (if any)

Supplementary bibliographical information

ISSN and key title
0280–5316

ISBN

Language
English

Number of pages
21

Security classification

Recipient's notes

1. Introduction

It is of great importance in the IVSS - *Road Friction Estimation*-project to measure the characteristics of a couple of representative tires. The proposed model-based approaches to estimate the tire-road friction require an accurate model validation and it is important to study how the tire behavior changes due to changed road condition. At the reported test occasion the reference measurements were performed by VTI at the test track Hällered owned by Volvo. Specific measurement data for the respective sub projects were recorded at the same time, but these are not further treated here. The major purpose of this report is to perform a validation of the brush model, which is intended to be used in the project, towards the measurement data collected by VTI. The parameters for best fit of the model at the different test conditions are presented in tables and the accuracy of the model is shown in diagrams as a comparison between the model performance and the experimental data.

1.1 Equipment

The test vehicle, denoted *BV12*, is a Scania truck LB80, owned and run by VTI and equipped with a fifth wheel for various measurements and slip and force excitations of tires for personal cars. The test wheel is pressed against the road by the pressure from a hydraulic cylinder, which can achieve different vertical loads in the range 1–6 kN. A varying brake torque can be applied on to the wheel through a disc brake controlled by a hydraulic brake system. The angle between the vehicle travel and the wheel rotational direction can also be changed during a test sequence. There are sensors on the wheel suspension for measurements of the vertical and horizontal forces and the vertical torque working on the wheel hub. There is also a sensor to measure the rotational velocity of the test wheel. The vehicle reference speed is obtained from the left-front wheel of the truck.

1.2 Measurement Procedure

The longitudinal tire data was generated by applying a braking torque on the wheel as a ramp function from free rolling to complete lock-up of the wheel. The lateral data was in a similar manner obtained by sweeping the wheel axle from zero [deg] to -20 [deg] and back. Some measurement sequences also included sweeps from zero to 20 [deg] and back. To reduce the number of performed tests one reference setup was chosen and the test conditions were changed one at a time from this setup to clearly visualize their effect on the tire behavior. The reference setup for pure braking and cornering was the winter tire on wet asphalt with a vertical load of 4 kN, see Table 1. The load dependence was measured by testing at the vertical loads 2, 4 and 6 kN. Further, dry asphalt was tested both for summer and winter tires. Results from low-friction surface were only obtained for the winter tire. Data from braking with the two slip angles ± 2 [deg] are also available, but not further treated here. For more information about the test sequences refer to the attached measurement scheme. The tested tire types were:

- Summer tire: Continental ContiSportContact 225/45R17 91W
- Winter tire: Continental ContiWinterContact TS810 215/55R16

Table 1 List over available test conditions. The reference test setup is written in italic text font.

Tire type	Road surface	Load	Combined slip only braking
Winter tire	*Wet asphalt*	*4 kN*	*0*
Winter tire	Wet asphalt	2 kN	0
Winter tire	Wet asphalt	6 kN	0
Winter tire	Low friction (basalt)	4 kN	0
Winter tire	Dry asphalt	4 kN	0
Winter tire	Low friction (basalt)	4 kN	$\alpha = \pm 2$ [deg]
Summer tire	Wet Asphalt	4 kN	0
Summer tire	Dry asphalt	2 kN	0

2. Data Validation

2.1 The Brush Model

Within the RFE sub-project working with model-based friction estimation, the brush model is considered to be used to describe the tire behavior. One of the major purposes with the measurements is to verify that the model predicts the tire behavior sufficiently good to be useful for friction estimation. The brush model describes the tire force as a function of the slip as

$$F_i = \begin{cases} -C_i\sigma_i + \frac{1}{3}\frac{C_i^2\sigma_i|\sigma_i|}{\mu F_z}\text{sign}(\sigma_i) - \frac{1}{27}\frac{(C_i\sigma_i)^3}{(\mu F_z)^2} & \text{if} \quad |\sigma_i| < \sigma_i^\circ \\ -\mu F_z \text{sign}(\sigma_i) & \text{otherwise} \end{cases} \tag{1}$$

where $\sigma_i^\circ = 3\mu F_z/C_i$. The model can be used both longitudinally ($i = x$) and laterally ($i = y$). Longitudinally, the σ-slip is defined as

$$\sigma_x = \frac{v_x - \omega R_e}{\omega R_e} \tag{2}$$

and laterally as

$$\sigma_y = \frac{v_y}{\omega R_e} \tag{3}$$

where v_x and v_y are the longitudinal and lateral velocity of the wheel hub, respectively. The rotational speed of the tested wheel is denoted by ω and R_e is its free rolling radius.

The brush model in the presented form is supposed to describe the longitudinal tire behavior well. The lateral behavior is, however, affected by the flexibility in the carcass which is neglected in 1. This may affect the agreement of the brush model in the lateral direction.

2.2 Summary of results

The brush-model parameters have been derived by optimizing the shape of the tire curve using a Gauss-Newton based method towards the measurement data. The data points in the low slip region up to just above the point for fully developed friction force for all repetitions within one test file, are used for the optimization. A further restriction is that the absolute value of the slip is increasing. The reason for this is that there is a hysteresis in the measurements when raising and lowering the slip.

The resulting parameter values are presented in Tables 2–5 and the brush model validation compared to the measurement data is shown in Figures 1–17. The tire force is normalized by the measured vertical force at the validation. The tire stiffness is assumed to be linearly load dependent as $C_i = C_{0i}F_z$, which eliminates the dependence of F_z in the right-hand expression of (1). Later on, it is shown that there is a minor load dependency even in C_{0i}. Some discrepancies in the fit may be explained by slip and force biases and the effect from the two different biases might be difficult to separate. The equipment is therefore, according to VTI, difficult to calibrate. The force bias and the bias on the lateral slip are caused by bias on the measurement sensors. The bias on the longitudinal slip may be explained by the error in the estimated free rolling wheel radius. The free rolling radius, R_e, is the rolling wheel radius when no force is transmitted by the tire and during these measurement it is identified before start up of the tests. There are, however, many factors such as temperature, tire pressure, wear and tire load that affect R_e. Hence, changes in the radius which may alter the slip bias has to be accounted for at each test sequence. The slip bias, often called horizontal shift, s_h, is related to changes in the wheel radius as

$$s_h \approx -\Delta r_0 = -\frac{\Delta R_e}{R_e} \tag{4}$$

In the low friction cases, the disturbances on the force measurements from, i.e. road irregularities, affect the tire characteristics considerably, which causes a less reliable determination of the optimal tire parameters.

Longitudinal properties It is left to the reader to qualitatively judge the validation of the brush model in the comparison to the data. From the Plots 1-7 it is obvious that the result of the model is well within the spread of the measurements. If the accuracy is sufficient for friction estimation is not yet clear and it is difficult to form an opinion before the algorithms are fully developed. The optimal longitudinal model parameters at the different test conditions are presented in Table 2 and for each test sequence in Table 4. In the braking case, the slip interval for the parameter optimization was 0.01-8 % for the low friction and 0.1-15 % for the high friction surface. The slip bias is derived by averaging the slip before the brake application. The values of the tire stiffness is very sensitive to the correction of the slip bias.

Table 2 Result of the parameter optimization in the longitudinal direction

Tire	Road condition	Tire Stiff.	Friction	s_h [%]	Comments
Winter	Wet asphalt	26-28	1	1.7	
Winter	dry asphalt	25	1.2	1.8	
Winter	Low friction	14 - 20	0.23-0.31	1.2	
Winter	Wet asphalt	22-25	1	1.2	$F_z = 2$ kN
Winter	Wet asphalt	27-29	1.1	1.9	$F_z = 6$ kN
Summer	Wet asphalt	41-45	1.1	1.1	
Summer	dry asphalt	36-39	1.2	1.0	

Lateral properties The agreement of the brush model to the data is shown in Figure 8-17. As in the longitudinal direction the model performance is within the spread of the measurements. Hence, it might be concluded that the effect of the flexibility of the carcass in the lateral direction do not largely deteriorate the validity of the brush model. It can, however, be seen as one of the reason why C_{0x} and C_{0y} differs. The flexible carcass should lower the stiffness, laterally.

In the lateral direction only data between 0.05 and 2 [deg] (low friction surface) and 0.2 and 10 [deg] (asphalt) from the first slip angle excitation is used for the optimization. For the low friction surface the force offset was corrected and it can be noticed that the results from sweeps with positive angle differs from sweeps with negative α, compare Figures 8 and 9. For the asphalt measurements the effect is less obvious and the correction was not necessary.

One remarkable observation is the large difference between the tire force for increasing and decreasing values of the slip angle. The force builds up earlier in the increasing case. This can not be explained by any dynamic effect in the tire, since this mostly results in a lower force for increasing slip than for decreasing, the opposite from here. Hence, it might be caused by undesired effects of the mechanical measurement arrangement. Note, that the force curves for increasing positive α agrees well to decreasing negative α. This report will not further deal with the origin of the error sources. But, it is empirically shown that the divergence can be reduced by the following corrections

$$\alpha = \hat{\alpha} + k_\alpha \frac{d\hat{\alpha}}{dt} \tag{5a}$$

$$F_y = \hat{F}_y - k_f \frac{d\hat{\alpha}}{dt} \tag{5b}$$

The correction of α might be explained by that the motion of the wheel do not agree with the measurements (marked by $\hat{}$), due to the turning of the wheel. Hence, the actual slip angle do not agree with the measured slip angle. The correction of the force can be necessary, since frictional torque due to the turning might affect the force measurements. It is recommended to study the effect of different change rates of α to be able to conclude if the measurement errors are caused by these dynamic effects, or other error sources have to be found. The issues is forwarded to VTI for further examination.

In Figures 18 and 19 the measurements with the corrections are shown, where k_α =0.65 and k_f =30. Here, all data within the slip range of interest is used for optimization, since the curves for increasing and decreasing tire force agree well. The tire stiffnesses from the optimization for both adjusted and unadjusted data are shown in Table 3.

2.3 Conclusions and remarks

Overall, it can be stated that the brush model predicts the tire behavior well. By a comparison between the parameter optimization from the different test conditions the following statements can be done:

- The summer tire is shown to be stiffer than the winter tire
- The friction coefficient is equal in longitudinal and lateral direction
- The normalized longitudinal tire stiffness of the winter tire decrease for increasing vertical loads, while it is the opposite in the lateral direction.

Table 3 Result of the parameter optimization in the lateral direction

Tire	**Road condition**	**Tire Stiff. Uncorr;Corr acc. (5)**	**Friction**	**Comments**
Winter	Wet asphalt	27-29; 20-21	1-1.1	
Winter	dry asphalt	24-28; 18-20	1.1-1.2	
Winter	Low friction	27-53; 19-29	0.24-0.3	
Winter	Wet asphalt	29-31; 22-23	1	$F_z = 2$ kN
Winter	Wet asphalt	22-23; 17-18	1-1.1	$F_z = 6$ kN
Summer	Wet asphalt	29-33; 22-23	1	
Summer	dry asphalt	29-35; 21-24	1.1	

- The tire stiffness is slightly lower for the dry asphalt than the wet asphalt
- The tire stiffness is lower for the low friction than the high friction surface (at least longitudinally)
- If the corrected data is used, the tires are less stiff in the lateral direction compare to the longitudinal direction.

There are some uncertainties in parameter optimization of the measurements from the low friction surface, since the force disturbances are large compared the low tire forces. The area of interest is in the slip range of 0-2 [deg] for this surface and this range is past in less than 0.3 s. Hence, the number of measurement points are considerably lower than for the tests on asphalt. It is, therefore, difficult and unreliable to draw too detailed conclusions from the low friction tests.

Based on the experience from the data evaluation the following changes in the measurement procedure are proposed:

- Slower change rate of the applied tire force are preferred instead of many applications. The fast sweeps hides the effect of disturbing oscillations in the measurements. Only fractions of the disturbing frequencies affect the data, which makes the plots smoother, but reduces the repeatability.
- Laterally, the sweeps might be performed from one side to the other and back. Hence from -20 [deg] to 20 [deg] and back to -20 [deg]. The biases in both the slip and the force measurements are then easily accounted for and the important zero point will be pasted in both positive and negative directions.
- The maximum slip angle might be decreased to save time and to allow slower sweeps. The present measurement shows that 10 [deg] is enough for the high friction surfaces and 5 [deg] for low friction with the actual tires.

Above this, VTI is emphasized to examine the reason for the difference of the lateral force measurements between increasing and decreasing magnitude of the slip angle, so that the cornering stiffness can be measured with better accuracy.

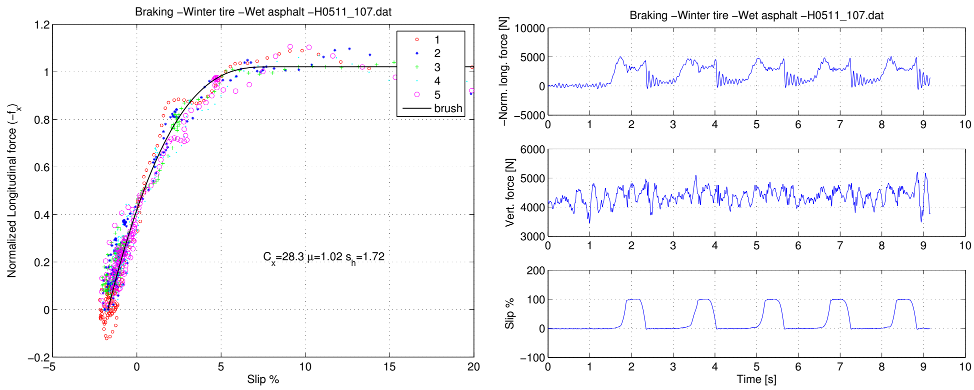

Figure 1 Results from braking test with winter tire on wet asphalt. The marking of the points in the left figure corresponds to the brake applications shown in the right figure. Only points during increasing slips are shown.

2.4 Acknowledgements

Many thanks to the test team from VTI that during a short, but intensive time slot provided the project with the great amount of valuable measurement data. Also, many thanks to the partners in the RFE-project for good planning and interesting cooperative work. Special acknowledgements to the participants in the RFE sub-project "Model-based road friction estimation" for careful proofreading and valuable opinions on this report.

A. Data Plots and Parameter Tables

In this section plots of comparisons between the data and the tire model are shown for selected tests. There are also tables presenting the optimal choice of parameters for each test sequence. Results from one test sequence at each test condition are shown in the plots. Mostly there are three sequences for each condition. The plots to the left show the measurement data in the force–slip plane together with the brush model with the optimized parameters. Data from the different slip excitation occasions are denote by different marks, which are indexed in the figure legend. The numbering corresponds to the slip excitations phases shown in the right figure, which covers the data from the entire test sequence. The longitudinal slip on the x-axis in the figures are calculated according to the λ-definition, $\lambda = (v_x - \omega R_e)/v_x$, which differs from the slip used as input to the brush model, compare (2).

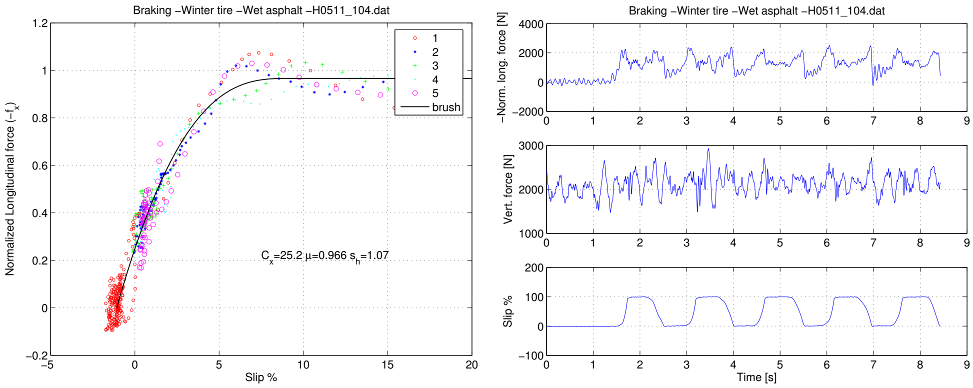

Figure 2 Results from braking test with winter tire on wet asphalt. The vertical load is 2 kN.

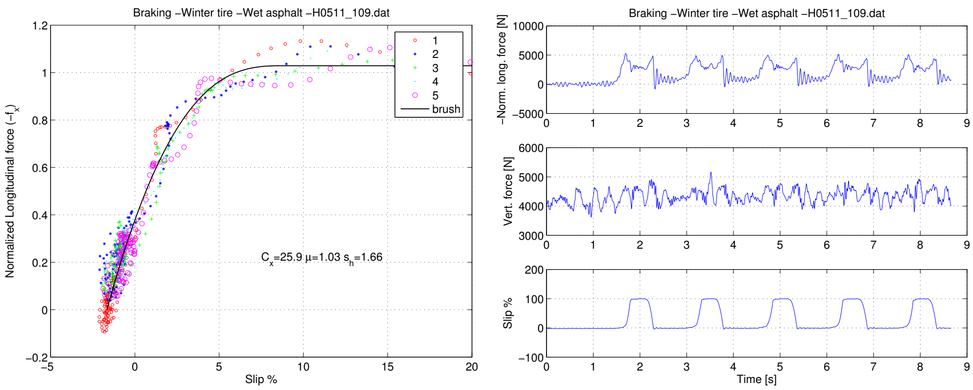

Figure 3 Results from braking test with winter tire on wet asphalt. The vertical load is 6 kN.

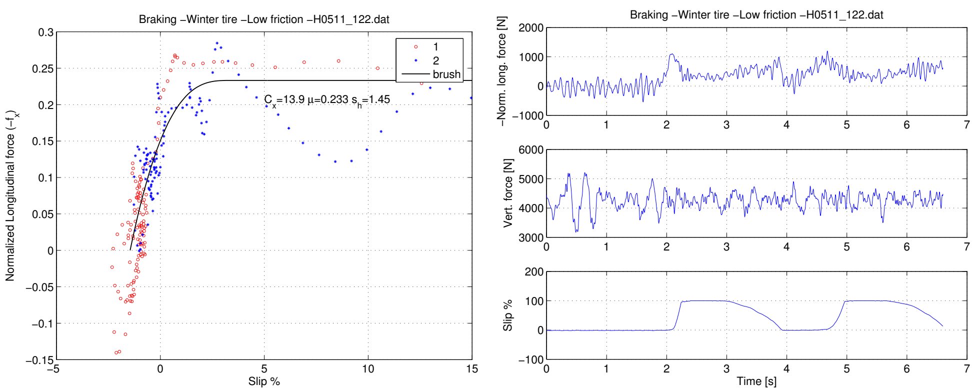

Figure 4 Results from braking test with winter tire on low friction surface.

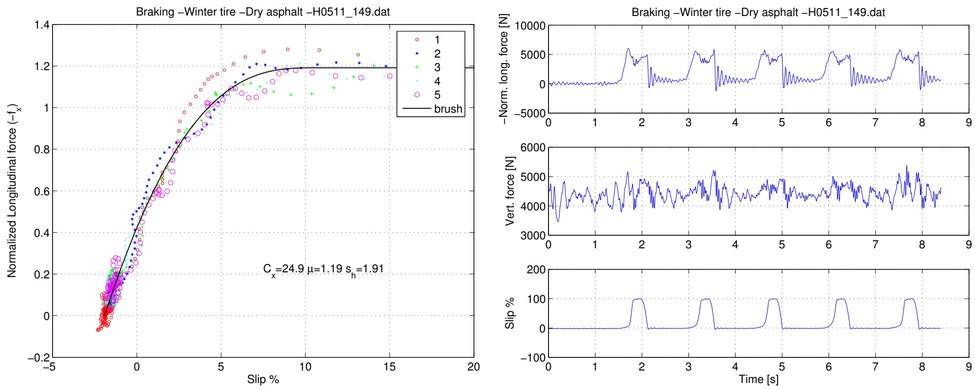

Figure 5 Results from braking test with winter tire on dry asphalt.

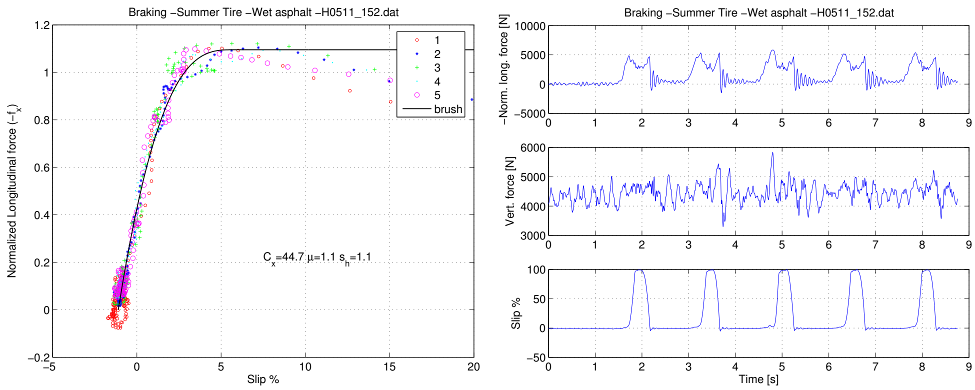

Figure 6 Results from braking test with summer tire on wet asphalt.

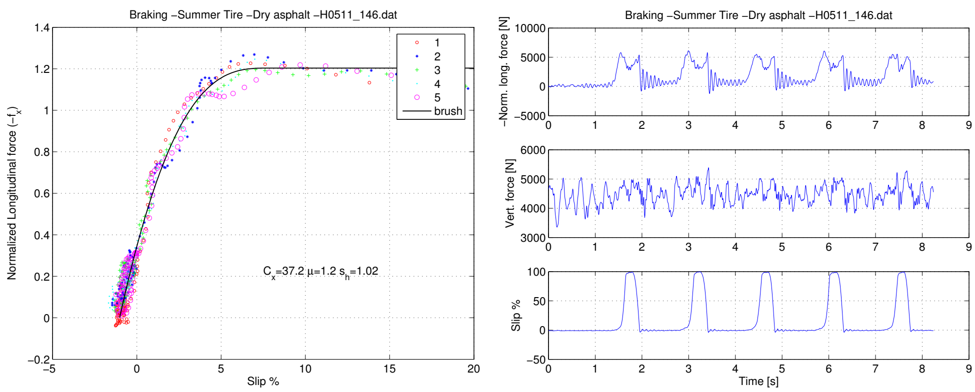

Figure 7 Results from braking test with summer tire on dry asphalt.

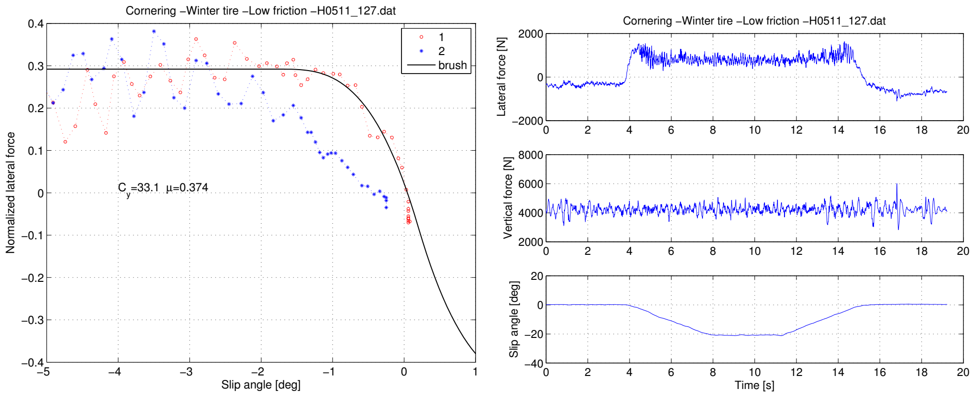

Figure 8 Results from cornering test with winter tire on low friction surface. The points marked as "1" in the left figure correspond to the slip-decrease sequence between 4–8 [s] in the right figure and the points marked as "2" correspond to the slip-increase sequence between 11–15 [s].

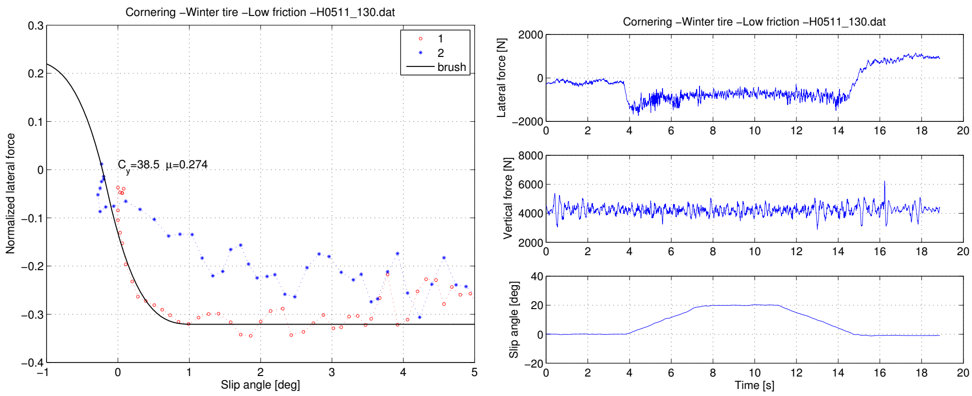

Figure 9 Results from cornering test with winter tire on low friction surface.

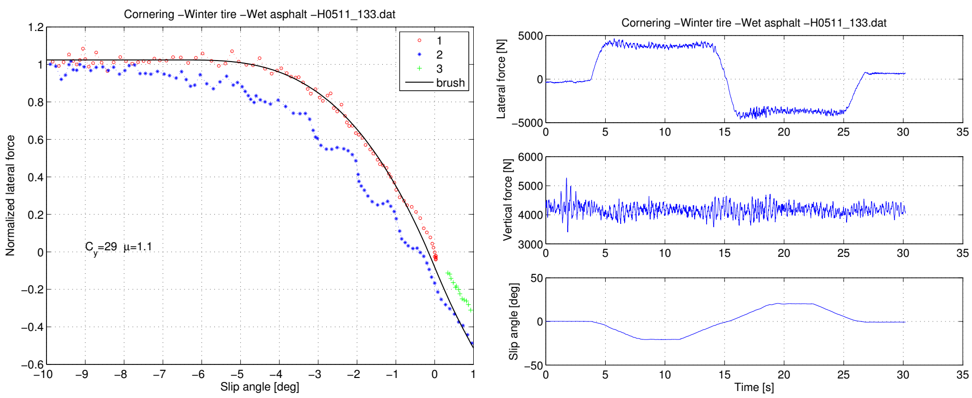

Figure 10 Results from cornering with the standard test setup. The last sweep of α is not reliable since it was performed on dry asphalt.

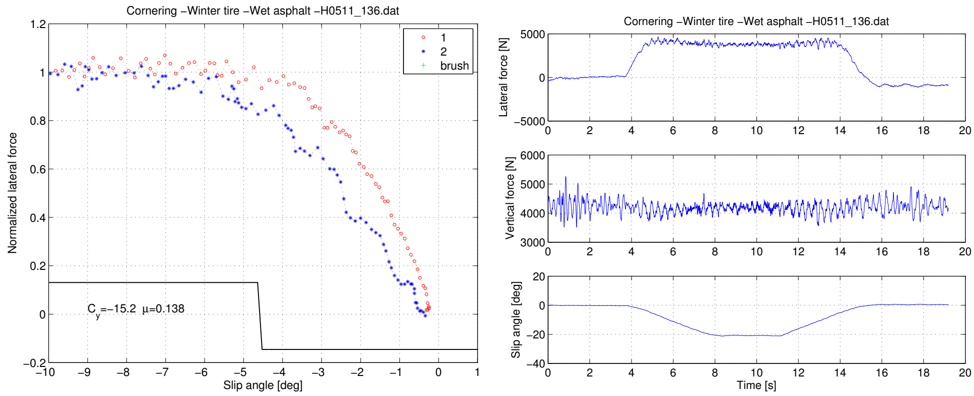

Figure 11 Results from cornering with the standard test setup.

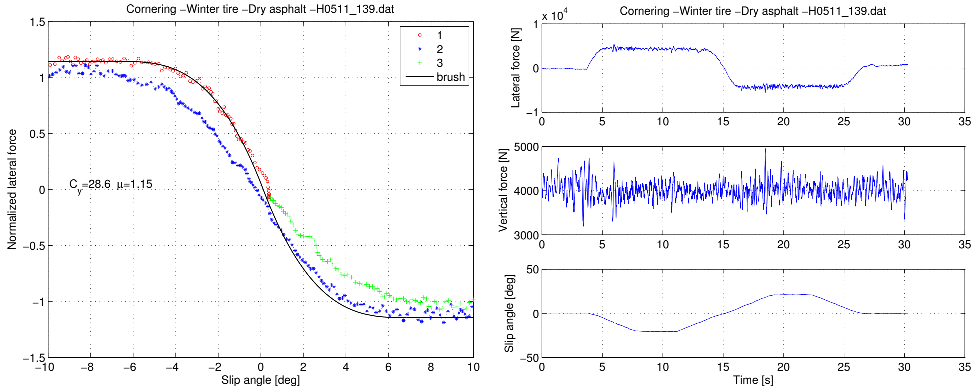

Figure 12 Results from cornering test with the winter tire on dry asphalt. The slip angle, α is swept from 0 to -20, and back to 0 [deg].

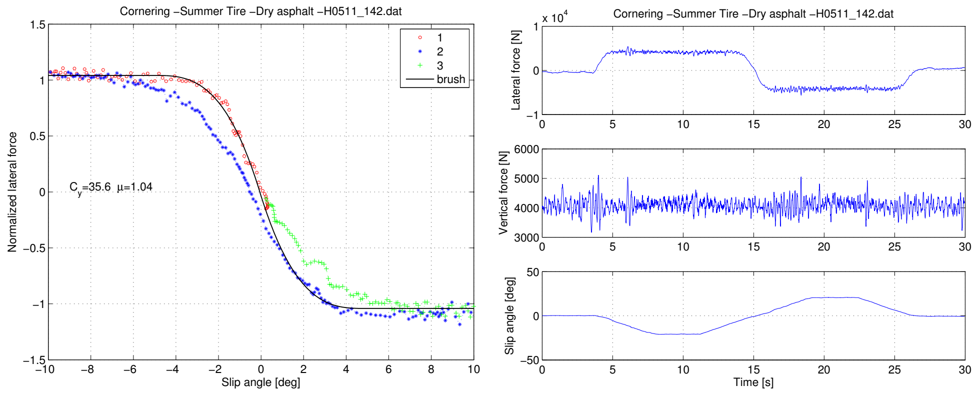

Figure 13 Results from cornering test with the summer tire on dry asphalt.

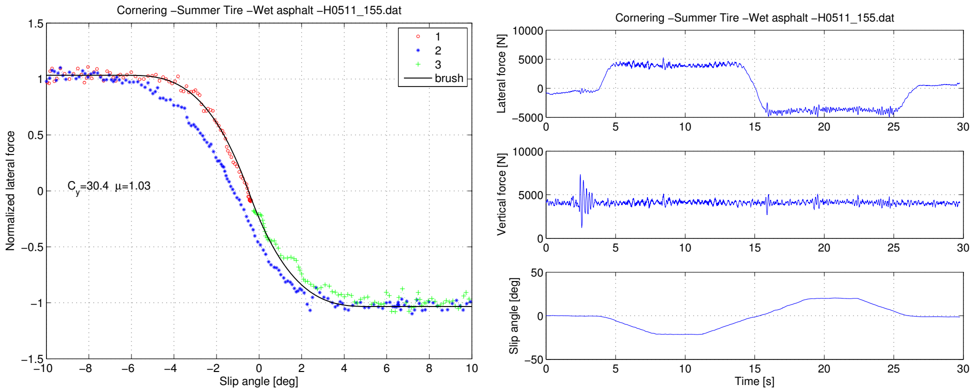

Figure 14 Results from cornering test with the summer tire on dry asphalt.

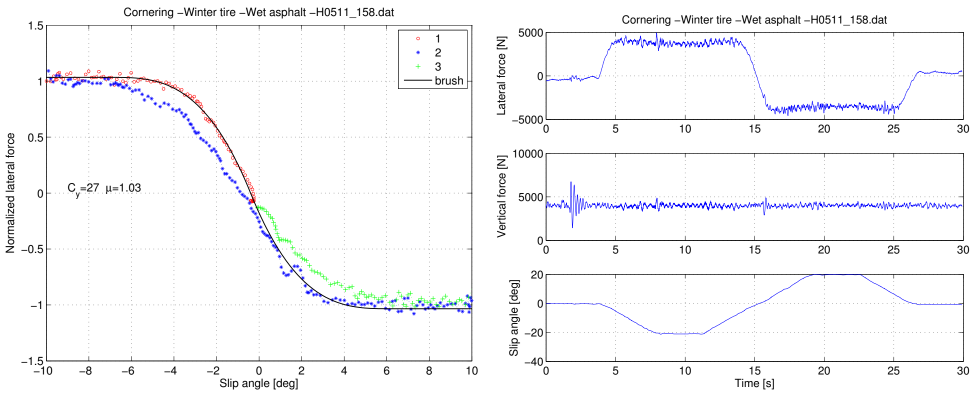

Figure 15 Cornering with the reference setup - Re-run.

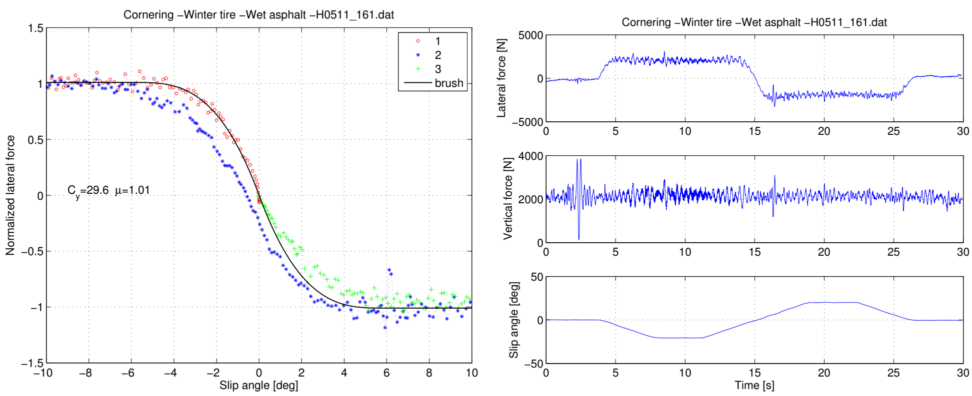

Figure 16 Results from cornering test with the winter tire on wet asphalt. The vertical load is 2 kN.

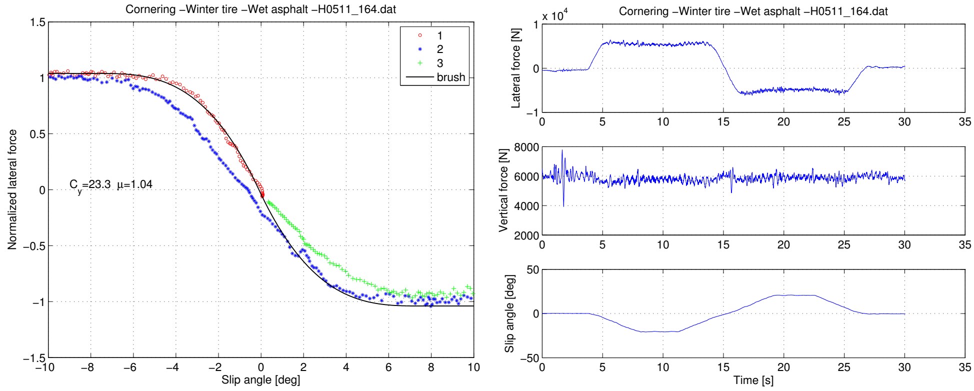

Figure 17 Results from cornering test with the winter tire on wet asphalt. The vertical load is 6 kN.

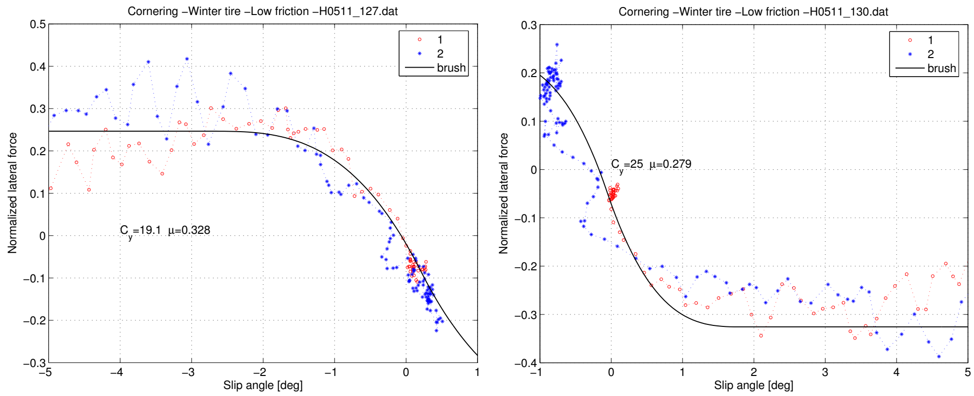

Figure 18 Correction of the slip angle and lateral force to eliminate the deviation in force between increasing and decreasing abs(α). Compare to Figure 8 and 9

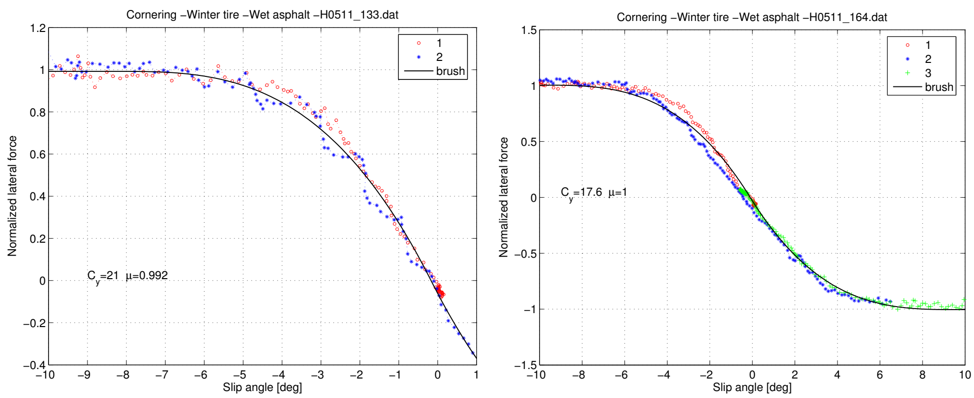

Figure 19 Correction of the slip angle and lateral force to eliminate the deviation in force between increasing and decreasing abs(α). Compare to Figure 10 and 17

Table 4 Parameter estimations from all longitudinal tests.

Description	C_x	μ	s_H [%]
Braking -Winter tire -Wet asphalt -H0511_104 -2kN	25.2	0.966	1.07
Braking -Winter tire -Wet asphalt -H0511_105 -2kN	22.2	0.987	1.17
Braking -Winter tire -Wet asphalt -H0511_106 -2kN	23.9	0.979	1.21
Braking -Winter tire -Wet asphalt -H0511_107	28.3	1.02	1.72
Braking -Winter tire -Wet asphalt -H0511_108	28.7	1.02	1.7
Braking -Winter tire -Wet asphalt -H0511_109	25.9	1.03	1.66
Braking -Winter tire -Wet asphalt -H0511_110 -6kN	27.4	1.07	1.98
Braking -Winter tire -Wet asphalt -H0511_111 -6kN	29	1.05	1.85
Braking -Winter tire -Wet asphalt -H0511_112 -6kN	27.9	1.07	1.94
Combined slip -Winter tire -Wet asphalt -H0511_113	21	1.01	1.69
Combined slip -Winter tire -Wet asphalt -H0511_114	22.8	0.976	1.66
Combined slip -Winter tire -Wet asphalt -H0511_115	21.1	0.989	1.67
Combined slip -Winter tire -Wet asphalt -H0511_116	26.3	1.02	1.27
Combined slip -Winter tire -Wet asphalt -H0511_117	25.3	1.02	1.44
Combined slip -Winter tire -Wet asphalt -H0511_118	21.1	1.08	1.71
Braking -Winter tire -Low friction -H0511_122	13.9	0.233	1.45
Braking -Winter tire -Low friction -H0511_123	19.4	0.25	1.22
Braking -Winter tire -Low friction -H0511_124	14.6	0.312	0.807
Braking -Summer Tire -Dry asphalt -H0511_146	37.2	1.2	1.02
Braking -Summer Tire -Dry asphalt -H0511_147	35.9	1.2	1.04
Braking -Summer Tire -Dry asphalt -H0511_148	38.9	1.2	0.929
Braking -Winter tire -Dry asphalt -H0511_149	24.9	1.19	1.91
Braking -Winter tire -Dry asphalt -H0511_150	25.1	1.17	1.78
Braking -Winter tire -Dry asphalt -H0511_151	24.7	1.16	1.68
Braking -Summer Tire -Wet asphalt -H0511_152	44.7	1.1	1.1
Braking -Summer Tire -Wet asphalt -H0511_153	42.7	1.09	1.12
Braking -Summer Tire -Wet asphalt -H0511_154	41	1.1	1.17

Table 5 Parameter estimations from all lateral tests.

Description	Normal		Adjusted	
	C_x	μ	C_x	μ
Cornering -Winter tire -Low friction -H0511_127	33.1	0.374	19.1	0.328
Cornering -Winter tire -Low friction -H0511_128	27.5	0.268	28.6	0.238
Cornering -Winter tire -Low friction -H0511_129	36.7	0.304	19.4	0.268
Cornering -Winter tire -Low friction -H0511_130	53.7	0.269	25	0.279
Cornering -Winter tire -Low friction -H0511_131	56.3	0.317	19.8	0.299
Cornering -Winter tire -Low friction -H0511_132	29.8	0.299	19.8	0.302
Cornering -Winter tire -Wet asphalt -H0511_133	27.6	1.02	21	0.992
Cornering -Winter tire -Wet asphalt -H0511_134	27.2	1	20.6	0.997
Cornering -Winter tire -Wet asphalt -H0511_135	27.1	1.01	21	0.998
Cornering -Winter tire -Wet asphalt -H0511_136	27.1	1.02	21	1
Cornering -Winter tire -Wet asphalt -H0511_137	24.7	1.03	20.7	1.01
Cornering -Winter tire -Wet asphalt -H0511_138	27.2	1.02	21.4	1.01
Cornering -Winter tire -Dry asphalt -H0511_139	28	1.15	19.8	1.1
Cornering -Winter tire -Dry asphalt -H0511_140	26.4	1.16	19	1.09
Cornering -Winter tire -Dry asphalt -H0511_141	24.3	1.16	17.9	1.12
Cornering -Summer Tire -Dry asphalt -H0511_142	35.2	1.04	23.8	1.05
Cornering -Summer Tire -Dry asphalt -H0511_143	32.1	1.13	22.3	1.09
Cornering -Summer Tire -Dry asphalt -H0511_144	29.5	1.16	21.1	1.1
Cornering -Summer Tire -Wet asphalt -H0511_155	30.9	1.03	22.4	1.03
Cornering -Summer Tire -Wet asphalt -H0511_156	29.5	1.06	22.7	1.04
Cornering -Summer Tire -Wet asphalt -H0511_157	32.8	1.05	24.4	1.04
Cornering -Winter tire -Wet asphalt -H0511_158	26.9	1.03	20.7	1.01
Cornering -Winter tire -Wet asphalt -H0511_159	27.1	1.02	20.8	1.01
Cornering -Winter tire -Wet asphalt -H0511_160	26.8	1.02	20.8	1.01
Cornering -Winter tire -Wet asphalt -H0511_161 -2kN	29.6	1.01	22.7	0.992
Cornering -Winter tire -Wet asphalt -H0511_162 -2kN	30.5	1	22	1
Cornering -Winter tire -Wet asphalt -H0511_163 -2kN	29.3	1.01	22.3	1
Cornering -Winter tire -Wet asphalt -H0511_164 -6kN	23.3	1.04	17.6	1
Cornering -Winter tire -Wet asphalt -H0511_165 -6kN	21.7	1.04	17.2	1.01
Cornering -Winter tire -Wet asphalt -H0511_166 -6kN	22.1	1.05	16.9	1.01

Tester VTI Hällered 8-9 november 2005

Vinterdäcket anges i mätfilen med kodnamn 1
Sommardäcket anges i mätfilen med kodnamn 2
Alla tester gjordes i 70 km/h

instruktioner om hur BV12-mätfilerna är uppbyggda finns i Blad2 i detta dokument

	Datum	Tid	Filnamn	Däck	Underlag	Typ av mätning	Slipvinkel	Last (kN)	Antal mät-kurvor	kommentar
1	2005-11-08	12:02	H0511_104.dat	Vinterdäck	våt asfalt	rak broms	0	2	5	
2	2005-11-08	12:06	H0511_105.dat	Vinterdäck	våt asfalt	rak broms	0	2	5	
3	2005-11-08	13:46	H0511_106.dat	Vinterdäck	våt asfalt	rak broms	0	2	5	
4	2005-11-08	13:53	H0511_107.dat	Vinterdäck	våt asfalt	rak broms	0	4	5	
5	2005-11-08	14:00	H0511_108.dat	Vinterdäck	våt asfalt	rak broms	0	4	5	
6	2005-11-08	14:04	H0511_109.dat	Vinterdäck	våt asfalt	rak broms	0	4	5	
7	2005-11-08	14:43	H0511_110.dat	Vinterdäck	våt asfalt	rak broms	0	6	5	
8	2005-11-08	14:47	H0511_111.dat	Vinterdäck	våt asfalt	rak broms	0	6	5	
9	2005-11-08	14:51	H0511_112.dat	Vinterdäck	våt asfalt	rak broms	0	6	5	
10	2005-11-08	15:03	H0511_113.dat	Vinterdäck	våt asfalt	kombinerad broms & slipvinkel	-2	4	4	Dessa tester börjar och
11	2005-11-08	15:15	H0511_114.dat	Vinterdäck	våt asfalt	kombinerad broms & slipvinkel	-2	4	4	avslutas med en rak bromsning.
12	2005-11-08	15:19	H0511_115.dat	Vinterdäck	våt asfalt	kombinerad broms & slipvinkel	-2	4	4	Däremellan är det 4 kombinerade
13	2005-11-08	15:25	H0511_116.dat	Vinterdäck	våt asfalt	kombinerad broms & slipvinkel	2	4	4	Bromsningar.
14	2005-11-08	15:28	H0511_117.dat	Vinterdäck	våt asfalt	kombinerad broms & slipvinkel	2	4	4	
15	2005-11-08	15:32	H0511_118.dat	Vinterdäck	våt asfalt	kombinerad broms & slipvinkel	2	4	4	
19	2005-11-08	15:59	H0511_122.dat	Vinterdäck	lågfriktion	rak broms	0	4	2	
20	2005-11-08	16:08	H0511_123.dat	Vinterdäck	lågfriktion	rak broms	0	4	2	
21	2005-11-08	16:12	H0511_124.dat	Vinterdäck	lågfriktion	rak broms	0	4	2	
24	2005-11-08	16:53	H0511_127.dat	Vinterdäck	lågfriktion	Styrsvep	0->-20->0	4	2	Endast svep från 0 till – 20 grad
25	2005-11-08	17:04	H0511_128.dat	Vinterdäck	lågfriktion	Styrsvep	0->-20->0	4	2	och tillbaka igen är ok. Det fortsatta
26	2005-11-08	17:10	H0511_129.dat	Vinterdäck	lågfriktion	Styrsvep	0->-20->0	4	2	Svepet skedde på torr asfalt.
27	2005-11-08	17:21	H0511_130.dat	Vinterdäck	lågfriktion	Styrsvep	0->+20->0	4	2	
28	2005-11-08	17:26	H0511_131.dat	Vinterdäck	lågfriktion	Styrsvep	0->+20->0	4	2	
29	2005-11-08	17:33	H0511_132.dat	Vinterdäck	lågfriktion	Styrsvep	0->+20->0	4	2	
30	2005-11-08	17:39	H0511_133.dat	Vinterdäck	våt asfalt	Styrsvep	0->-20->0	4	2	Endast svep från 0 till -20 grad

31	2005-11-08	17:44	H0511_134.dat	Vinterdäck	våt asfalt	Styrsvep	0->-20->0	4	2	och tillbaks igen är ok. Det fortsatta
32	2005-11-08	17:48	H0511_135.dat	Vinterdäck	våt asfalt	Styrsvep	0->-20->0	4	2	svepet skedde på torr asfalt.
33	2005-11-08	17:52	H0511_136.dat	Vinterdäck	våt asfalt	Styrsvep	0->-20->0	4	2	egentligen skulle dessa svep
34	2005-11-08	17:56	H0511_137.dat	Vinterdäck	våt asfalt	Styrsvep	0->-20->0	4	2	vara upp till +20 grader.
35	2005-11-08	18:00	H0511_138.dat	Vinterdäck	våt asfalt	Styrsvep	0->-20->0	4	2	
36	2005-11-09	09:49	H0511_139.dat	Vinterdäck	Torr asfalt	Styrsvep	0->-20->+20->0	4	4	
37	2005-11-09	09:56	H0511_140.dat	Vinterdäck	Torr asfalt	Styrsvep	0->-20->+20->0	4	4	
38	2005-11-09	10:01	H0511_141.dat	Vinterdäck	Torr asfalt	Styrsvep	0->-20->+20->0	4	4	
39	2005-11-09	11:26	H0511_142.dat	Sommardäck	Torr asfalt	Styrsvep	0->-20->+20->0	4	4	
40	2005-11-09	11:30	H0511_143.dat	Sommardäck	Torr asfalt	Styrsvep	0->-20->+20->0	4	4	
41	2005-11-09	11:33	H0511_144.dat	Sommardäck	Torr asfalt	Styrsvep	0->-20->+20->0	4	4	
43	2005-11-09	12:14	H0511_146.dat	Sommardäck	Torr asfalt	rak broms	0	4	5	
44	2005-11-09	12:18	H0511_147.dat	Sommardäck	Torr asfalt	rak broms	0	4	5	
45	2005-11-09	12:22	H0511_148.dat	Sommardäck	Torr asfalt	rak broms	0	4	5	
46	2005-11-09	12:40	H0511_149.dat	Vinterdäck	Torr asfalt	rak broms	0	4	5	
47	2005-11-09	12:43	H0511_150.dat	Vinterdäck	Torr asfalt	rak broms	0	4	5	
48	2005-11-09	12:47	H0511_151.dat	Vinterdäck	Torr asfalt	rak broms	0	4	5	
49	2005-11-09	14:05	H0511_152.dat	Sommardäck	våt asfalt	rak broms	0	4	5	
50	2005-11-09	14:08	H0511_153.dat	Sommardäck	våt asfalt	rak broms	0	4	5	
51	2005-11-09	14:14	H0511_154.dat	Sommardäck	våt asfalt	rak broms	0	4	5	
52	2005-11-09	14:25	H0511_155.dat	Sommardäck	våt asfalt	Styrsvep	0->-20->+20->0	4	4	
53	2005-11-09	14:30	H0511_156.dat	Sommardäck	våt asfalt	Styrsvep	0->-20->+20->0	4	4	
54	2005-11-09	14:34	H0511_157.dat	Sommardäck	våt asfalt	Styrsvep	0->-20->+20->0	4	4	
55	2005-11-09	14:47	H0511_158.dat	Vinterdäck	våt asfalt	Styrsvep	0->-20->+20->0	4	4	Detta är omkörning av
56	2005-11-09	14:51	H0511_159.dat	Vinterdäck	våt asfalt	Styrsvep	0->-20->+20->0	4	4	gårdagens körningar som ej blev ok.
57	2005-11-09	14:55	H0511_160.dat	Vinterdäck	våt asfalt	Styrsvep	0->-20->+20->0	4	4	
58	2005-11-09	15:04	H0511_161.dat	Vinterdäck	våt asfalt	Styrsvep	0->-20->+20->0	2	4	
59	2005-11-09	15:07	H0511_162.dat	Vinterdäck	våt asfalt	Styrsvep	0->-20->+20->0	2	4	
60	2005-11-09	15:10	H0511_163.dat	Vinterdäck	våt asfalt	Styrsvep	0->-20->+20->0	2	4	
61	2005-11-09	15:15	H0511_164.dat	Vinterdäck	våt asfalt	Styrsvep	0->-20->+20->0	6	4	
62	2005-11-09	15:18	H0511_165.dat	Vinterdäck	våt asfalt	Styrsvep	0->-20->+20->0	6	4	
63	2005-11-09	15:22	H0511_166.dat	Vinterdäck	våt asfalt	Styrsvep	0->-20->+20->0	6	4	

Mätdata är samplat i 200Hz och ges i 20 st kolumner för varje mätpunkt. De flesta data är uppmätta storheter medan några är våra interna styrsignaler.

Kolumn	betydelse	enhet	kommentar
1	Samplingsnr		
2	Tidpunkt	sekunder	
3	Sträcka	meter	
4	x-kraft	N	positiv riktning bakåt mot färdriktningen
5	y-kraft	N	positiv riktning höger mot färdriktningen
6	z-kraft	N	
7	momentkraft	N	
8	uppmätt slipvinkel	grader	ges av cykelhjulet bak på BV12. Avviker ibland något från satt slipvinkel
9	satt slipvinkel	grader	vinkel mellan mäthjul och fordon. Tar inte hänsyn till fordonets avvikelse från färdriktningen
10	färdhastighet	km/h	
11	mäthjulets rotationshastighet	km/h	
12	intern kanal		
13	intern kanal		
14	intern kanal		
15	intern kanal		
16	slip	%	
17	mux		frikionsvärdet i longitudinell riktning
18	uppmätt slipvinkel	grader	kopia av kolumn 8
19	muy		frikionsvärdet i lateral riktning
20	intern kanal		