Master of Science in Mechatronics Engineering

Tyre data fitting

Professor:
Francesco Biral

Students:

Cardone Andrea	224836
Sara De Godenz	222217
Francesco Mazzoni	224840

Department of Industrial Engineering

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1 Introduction

In the following report the results of the fitting procedure are shown. For every fitting step are reported the images related to the experimental and fitted data for both front and rear tyre and a table reporting the fitting results. The fitting procedure was carried out as suggested in the lesson. In particular the $V_x = 45\,m/s$ is chosen as the nominal velocity, considering the sports use of the tyres.

2 Longitudinal force fitting F_x

2.1 Fitting with nominal values

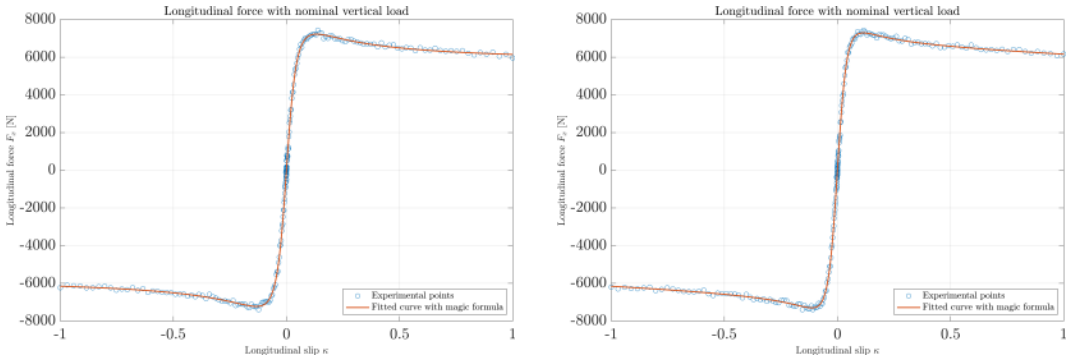

Figure 1: Longitudinal force fitting, front tyre(left) and rear tyre(right).

Type of tyre	R^2	RMSE	NRMSE
Front	0.9996	120.3150	0.0190
Rear	0.9996	122.4411	0.0190

2.2 Fitting with variable vertical load F_z

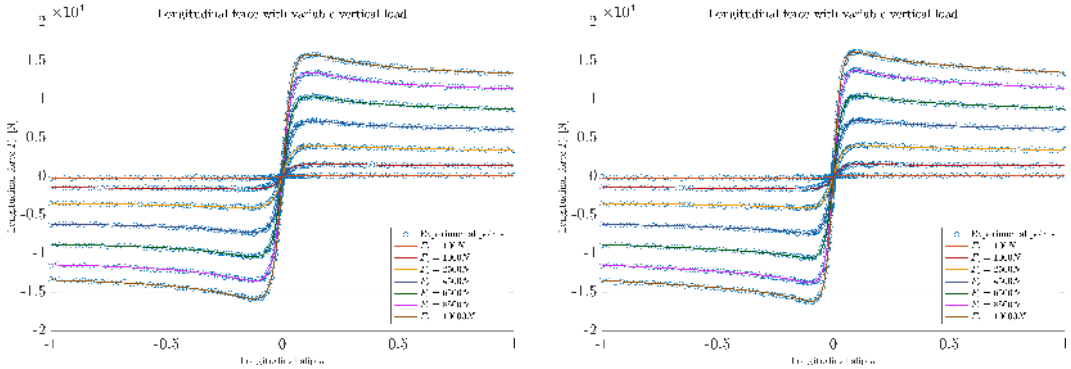

Figure 2: Longitudinal force fitting with variable vertical load, front tyre(left) and rear tyre(right).

Type of tyre	R^2	RMSE	NRMSE
Front	0.9997	140.6629	0.0171
Rear	0.9996	168.6235	0.0200

2.3 Fitting with variable camber angle γ

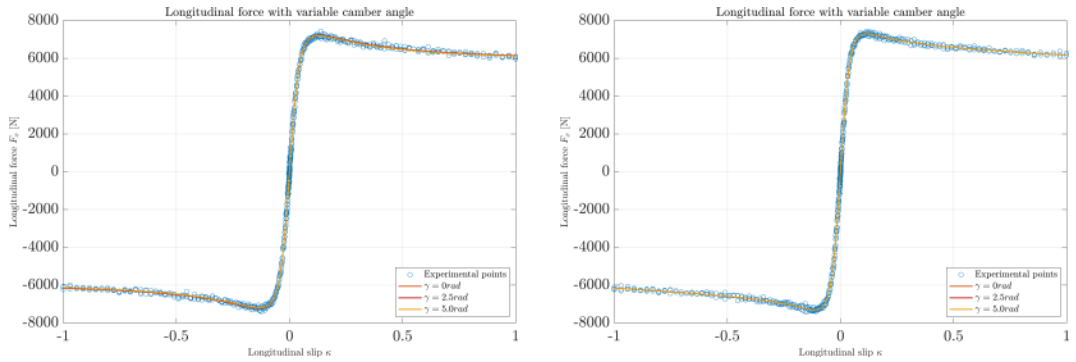

Figure 3: Longitudinal force fitting with variable vertical camber angle, front tyre(left) and rear tyre(right).

Type of tyre	R^2	RMSE	NRMSE
Front	0.9997	96.5588	0.0152
Rear	0.9996	119.1966	0.0185

2.4 Fitting with combined behaviour

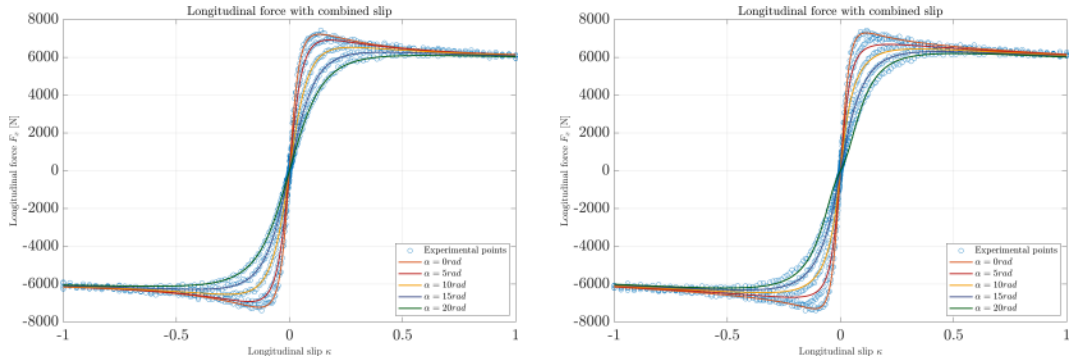

Figure 4: Combined longitudinal force fitting with variable vertical camber angle, front tyre(left) and rear tyre(right).

Type of tyre	R^2	RMSE	NRMSE
Front	0.9999	69.1660	0.0121
Rear	0.9998	70.9768	0.0123

3 Vertical force fitting F_y

3.1 Fitting with nominal values

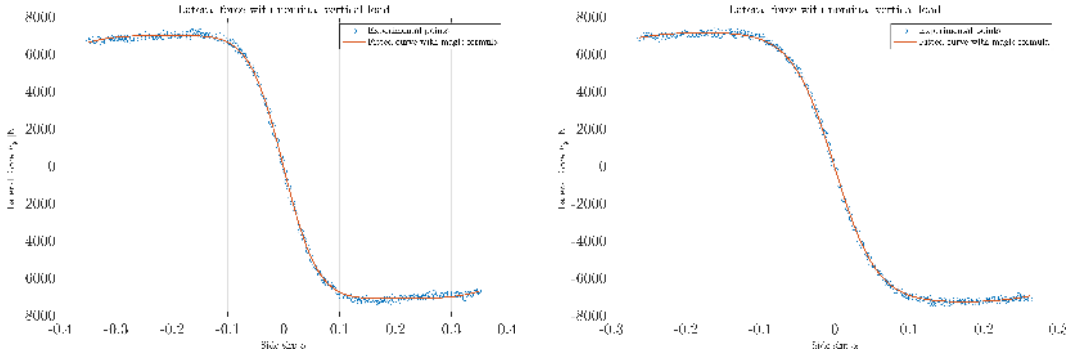

Figure 5: Lateral force fitting, front tyre(left) and rear tyre(right).

Type of tyre	R^2	RMSE	NRMSE
Front	0.9999	76.9036	0.0106
Rear	0.9999	84.7290	0.0119

3.2 Fitting with variable vertical load F_z

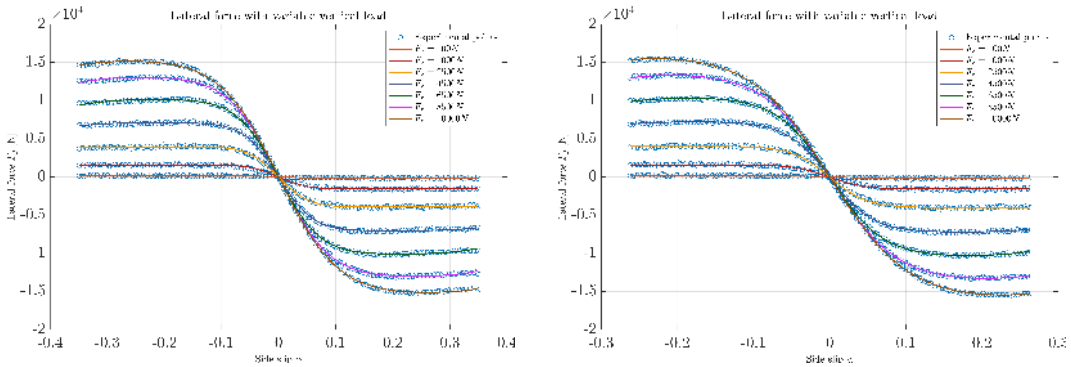

Figure 6: Lateral force fitting varying vertical load, front tyre(left) and rear tyre(right).

Type of tyre	R^2	RMSE	NRMSE
Front	0.9999	66.4194	0.0076
Rear	0.9999	64.6065	0.0076

3.3 Fitting with variable camber angle γ

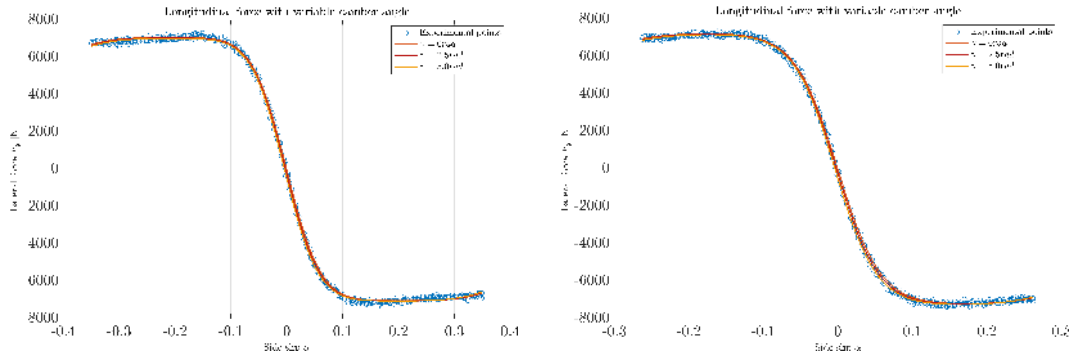

Figure 7: Lateral force fitting varying camber angle, front tyre(left) and rear tyre(right).

Type of tyre	R^2	RMSE	NRMSE
Front	0.9999	46.4331	0.0064
Rear	0.9998	57.8666	0.0081

3.4 Fitting with combined behaviour

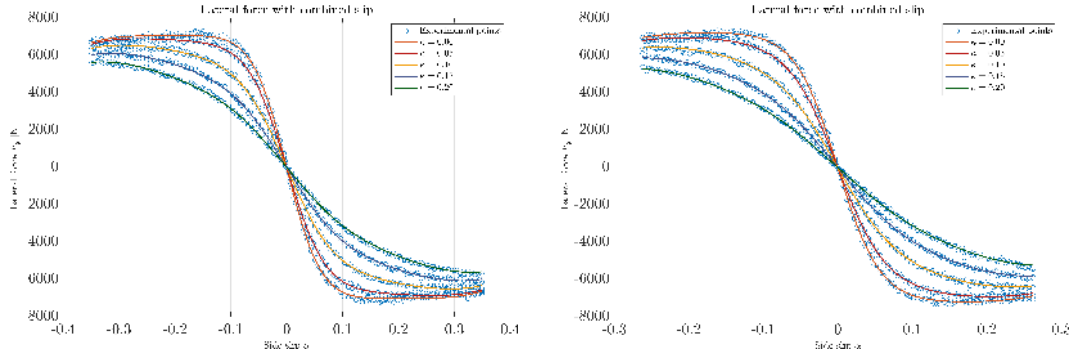

Figure 8: Combined lateral force fitting, front tyre(left) and rear tyre(right).

Type of tyre	R^2	RMSE	NRMSE
Front	0.9999	46.5136	0.0074
Rear	0.9994	150.1254	0.0254

4 Turning moment fitting M_z

4.1 Fitting with nominal values

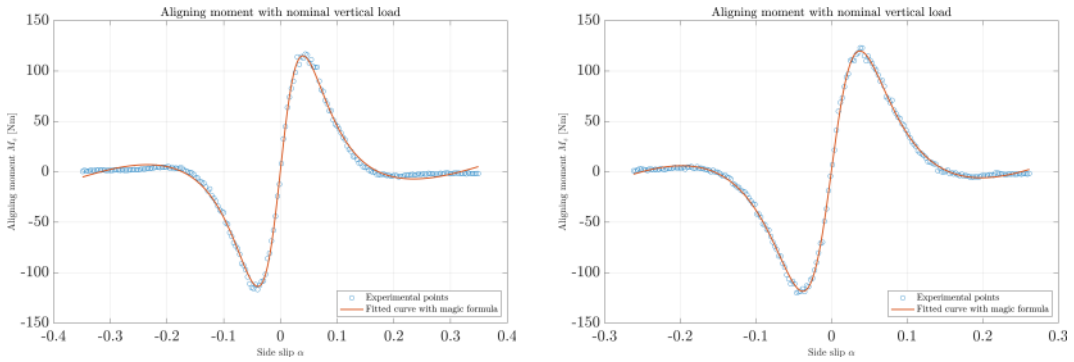

Figure 9: Aligning moment fitting nominal case, front tyre(left) and rear tyre(right).

Type of tyre	R^2	RMSE	NRMSE
Front	0.9978	2.6095	0.0473
Rear	0.9986	2.3997	0.0378

4.2 Fitting with variable vertical load F_z

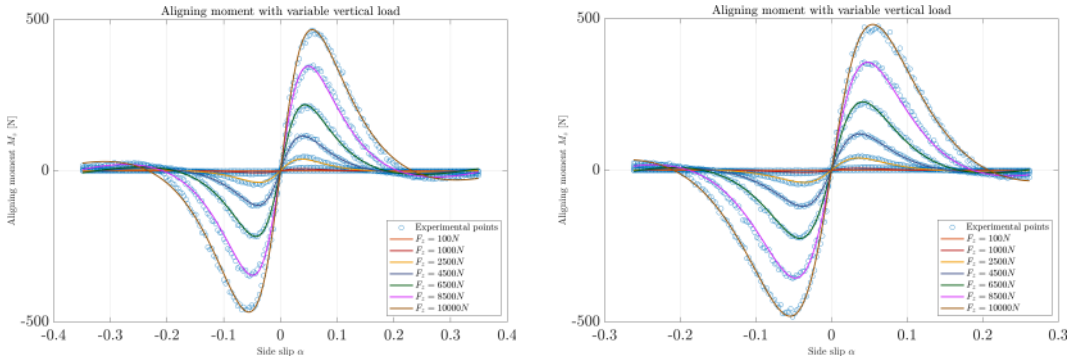

Figure 10: Aligning moment fitting varying vertical load, front tyre(left) and rear tyre(right).

Type of tyre	R^2	RMSE	NRMSE
Front	0.9999	5.8162	0.0431
Rear	0.9999	6.4044	0.0413

4.3 Fitting with variable camber angle γ

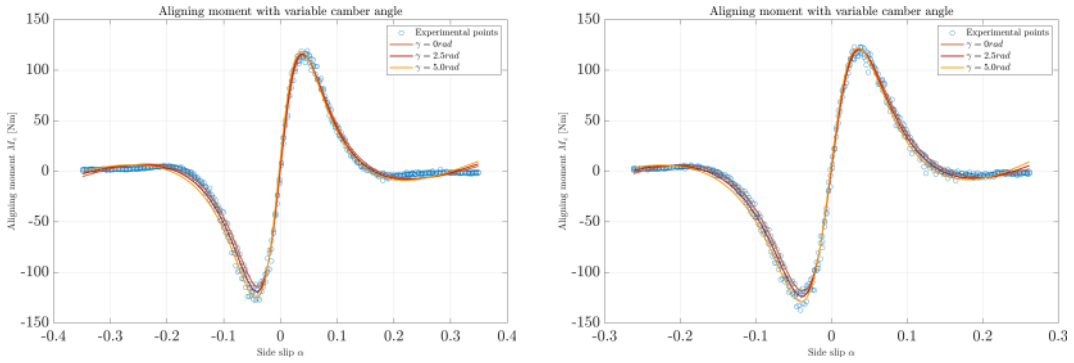

Figure 11: Aligning moment fitting varying camber angle, front tyre(left) and rear tyre(right).

Type of tyre	R^2	RMSE	NRMSE
Front	0.9959	3.4760	0.0613
Rear	0.9966	3.6074	0.0554

5 G_{xa} and G_{ya} plotted functions

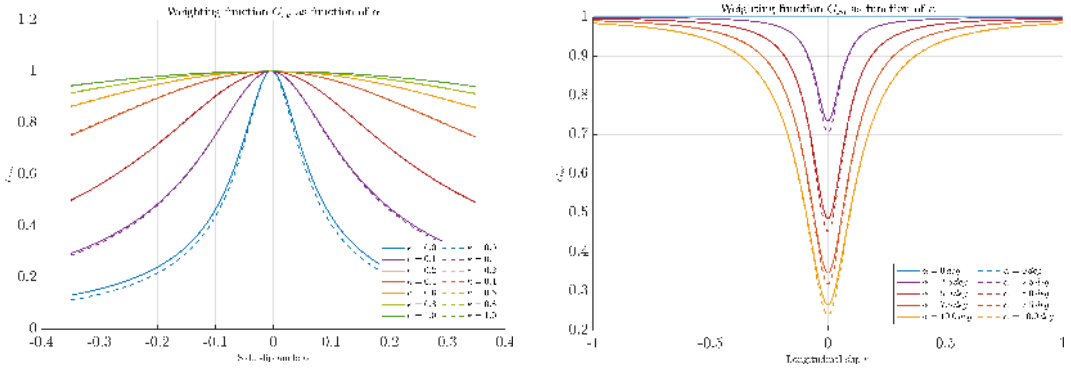

Figure 12: Weighting function G_{xa} of front tyre (continuous line) and rear tyre (dashed line), depending on α (left) and κ (right)

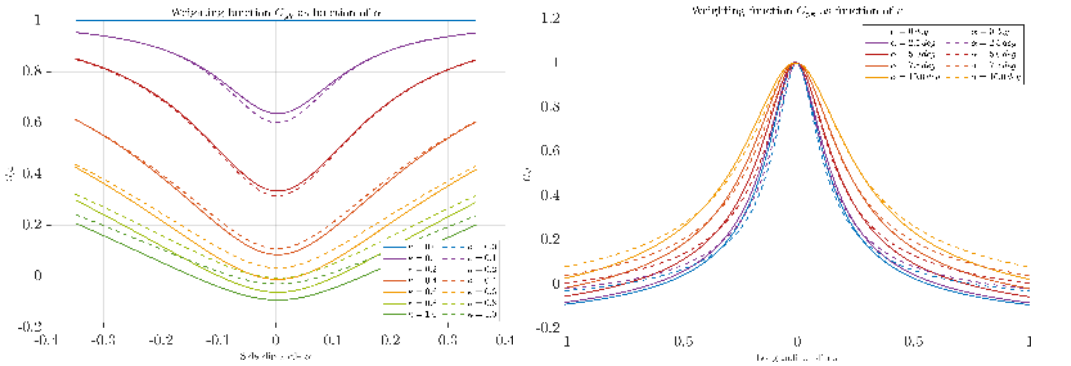

Figure 13: Weighting function G_{yk} of front tyre (continuous line) and rear tyre (dashed line), depending on α (left) and κ (right)

6 Fitting of ρ function

The fitting procedure for ρ was done by parts. First we fitted the coefficient a_3, than the coefficient c_1 multiplying γ and finally we fitted the remaining coefficients. After each fitting procedure, we calculated the values of R^2, RMSE and NRMSE.

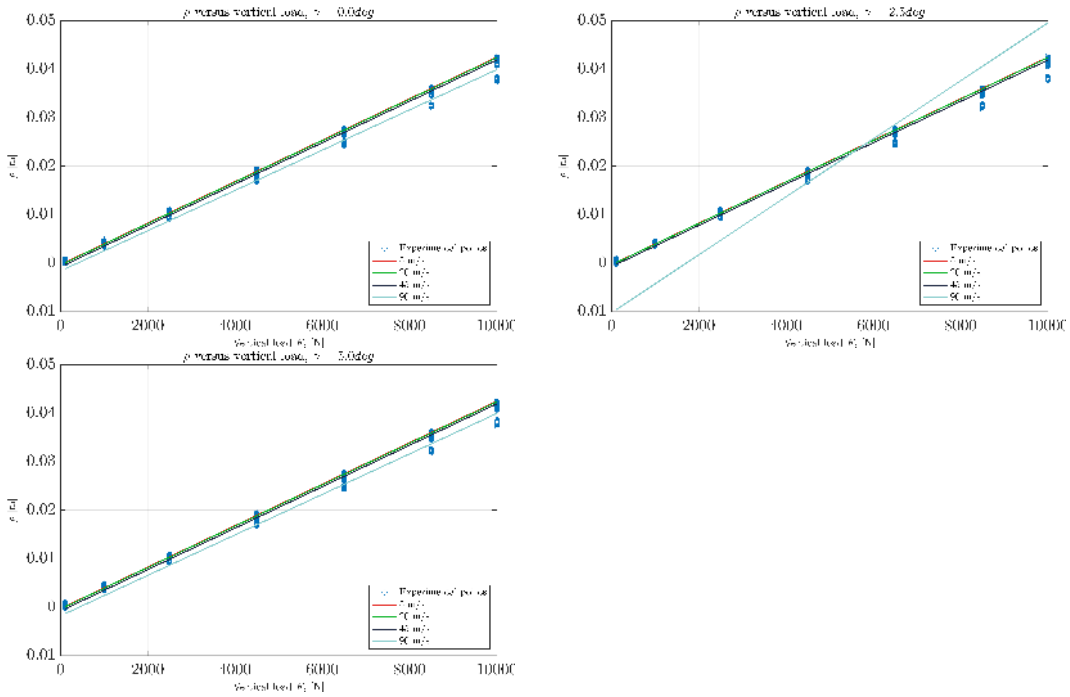

Figure 14: Front ρ data plot at different velocities, with $\gamma = 0.0^o$, $\gamma = 2.5^o$ and $\gamma = 5.0^o$

Front tyre	R^2	RMSE	NRMSE
After a_3	0.9982	0.010	0.0426
After c_1	0.9982	0.010	0.0427
Remaining coefficients	0.9994	$6.0926 \cdot 10^{-4}$	0.0252

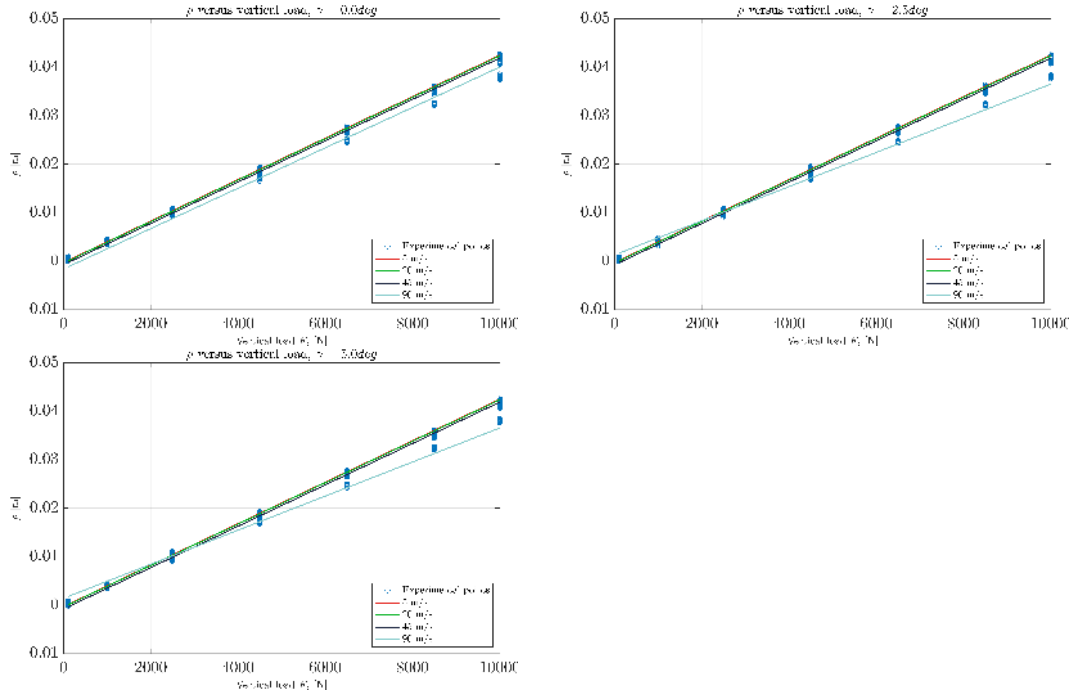

Figure 15: Rear ρ data plot at different velocities, with $\gamma = 0.0^o$, $\gamma = 2.5^o$ and $\gamma = 5.0^o$

Rear tyre	R^2	RMSE	NRMSE
After a_3	0.9982	0.010	0.0426
After c_1	0.9982	0.010	0.0428
Remaining coefficients	0.9994	$6.0127 \cdot 10^{-4}$	0.0249

7 Extra analysis: improving the fitting of ρ

We tried to add an extra term in the formula of ρ, i.e. the square root of the vertical load multiplied by a coefficient to be optimally found. This extra term is at the numerator. The reason for adding this kind of extra term is because after the first part of the fitting we noticed that the optimal points were more displaced from the experimental ones as the vertical force increased. This kind of divergence can be reduced by subtracting a square root function. Results in terms of errors are better than the nominal case. The new expression for the calculation of ρ is the following:

$$\rho = \frac{F_z + a4 \cdot \sqrt{F_z}}{a1 \cdot V^2 + a2 \cdot V + a3 + c1 \cdot \gamma^2} + b1 \cdot V^2 + b2 \cdot V \tag{1}$$

There are some improvements with respect to the nominal case in terms of root mean square error and its normalized value.

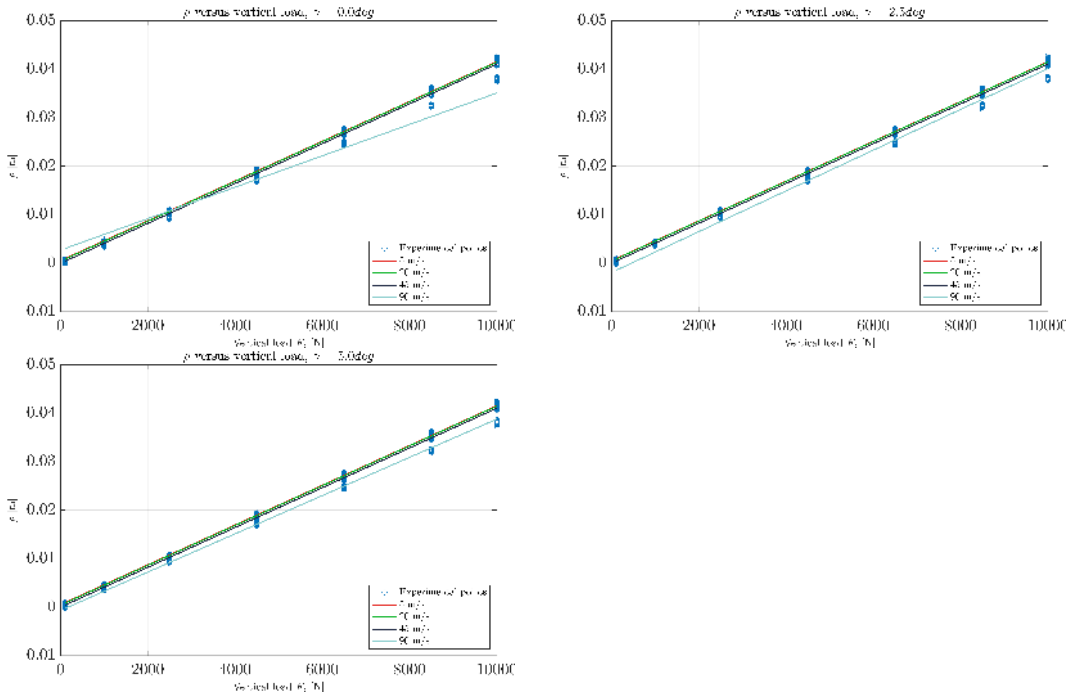

Figure 16: Front ρ data plot, $\gamma = 0.0^o$, $\gamma = 2.5^o$, $\gamma = 5.0^o$

Front tyre	R^2	RMSE	NRMSE
After a_3	0.9999	$1.9774 \cdot 10^{-4}$	0.0082
After c_1	0.9999	$1.9819 \cdot 10^{-4}$	0.0082
Remaining coefficients	0.9999	$1.9852 \cdot 10^{-4}$	0.0082

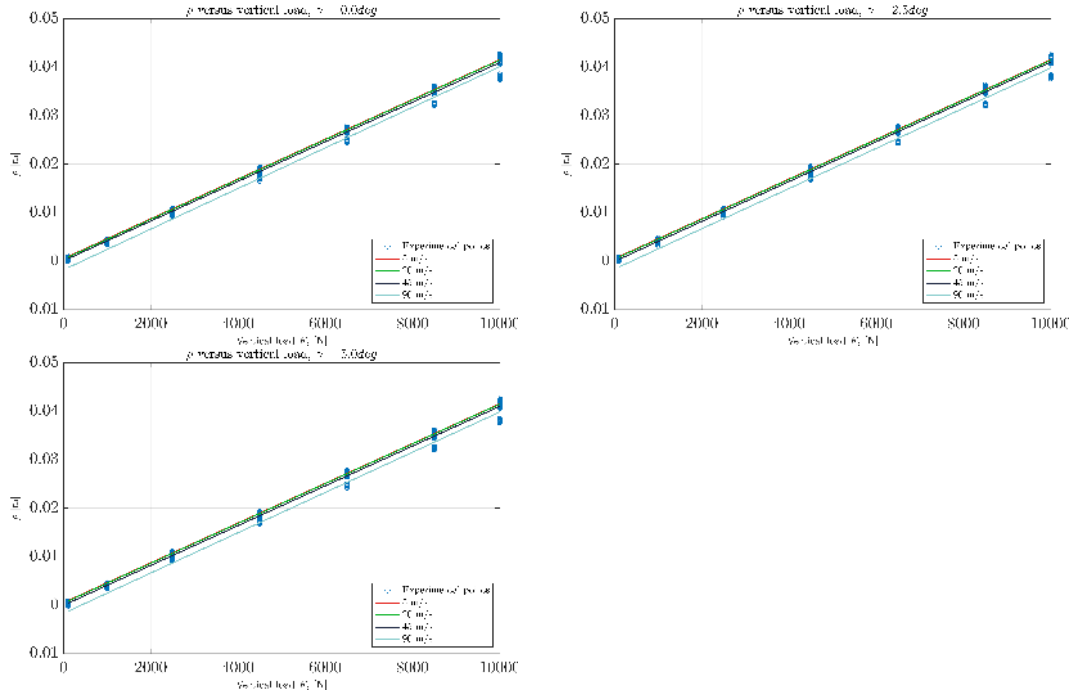

Figure 17: Rear ρ data plot, $\gamma = 0.0^o$, $\gamma = 2.5^o$, $\gamma = 5.0^o$

Rear tyre	R^2	RMSE	NRMSE
After a_3	0.9999	$1.9774 \cdot 10^{-4}$	0.0082
After c_1	0.9999	$1.9819 \cdot 10^{-4}$	0.0082
Remaining coefficients	0.9999	$1.9852 \cdot 10^{-4}$	0.0082