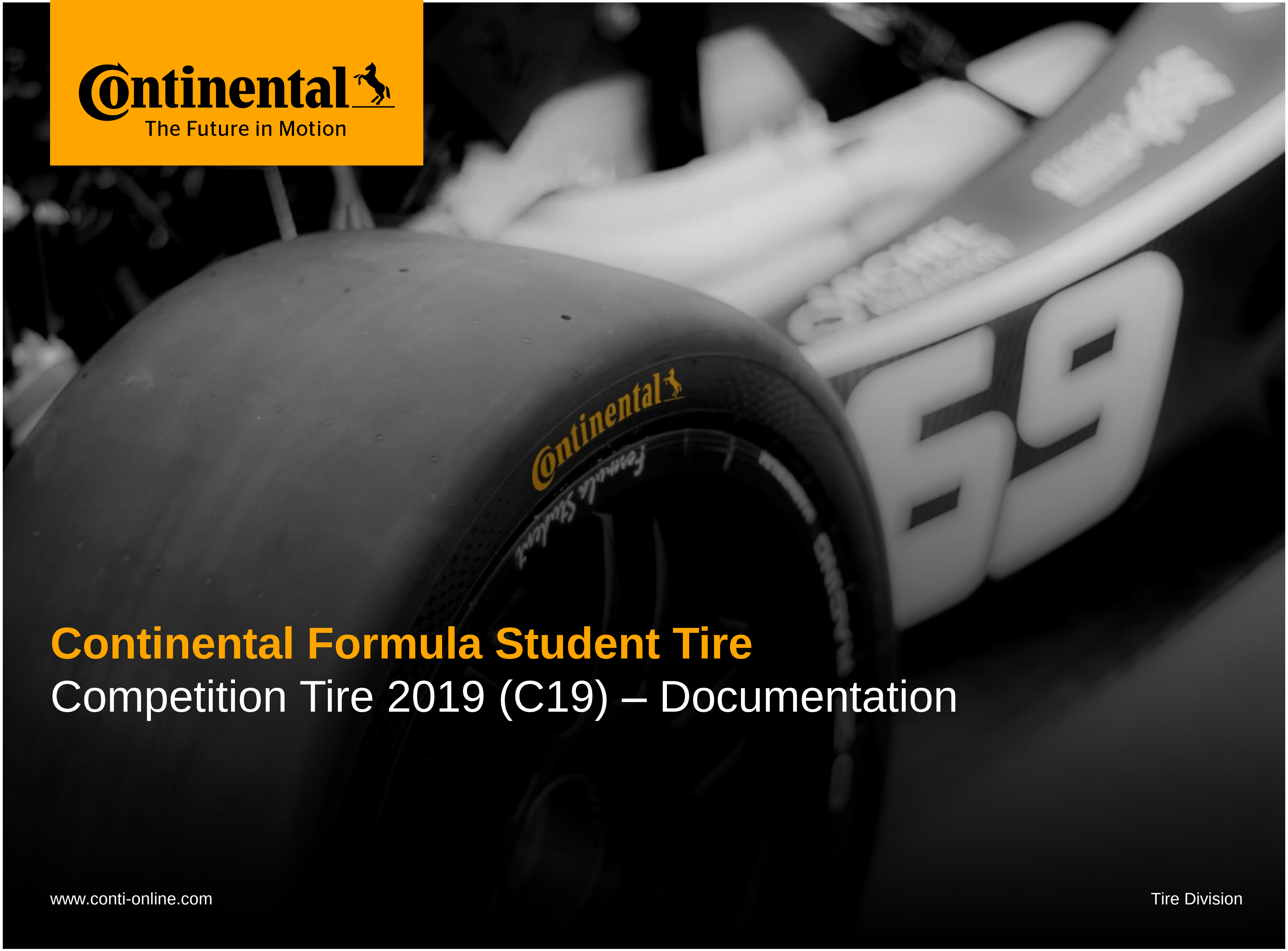


Continental
The Future in Motion

Continental Formula Student Tire

Competition Tire 2019 (C19) – Documentation

Introduction

Dear Formula Student Teams,

with this document we would like to inform you about the characteristics of the 2019 Formula Student Tire, namely “C19”.

All characteristics presented in this report are based on the slick tire mounted on a 7 x 13 inch rim.

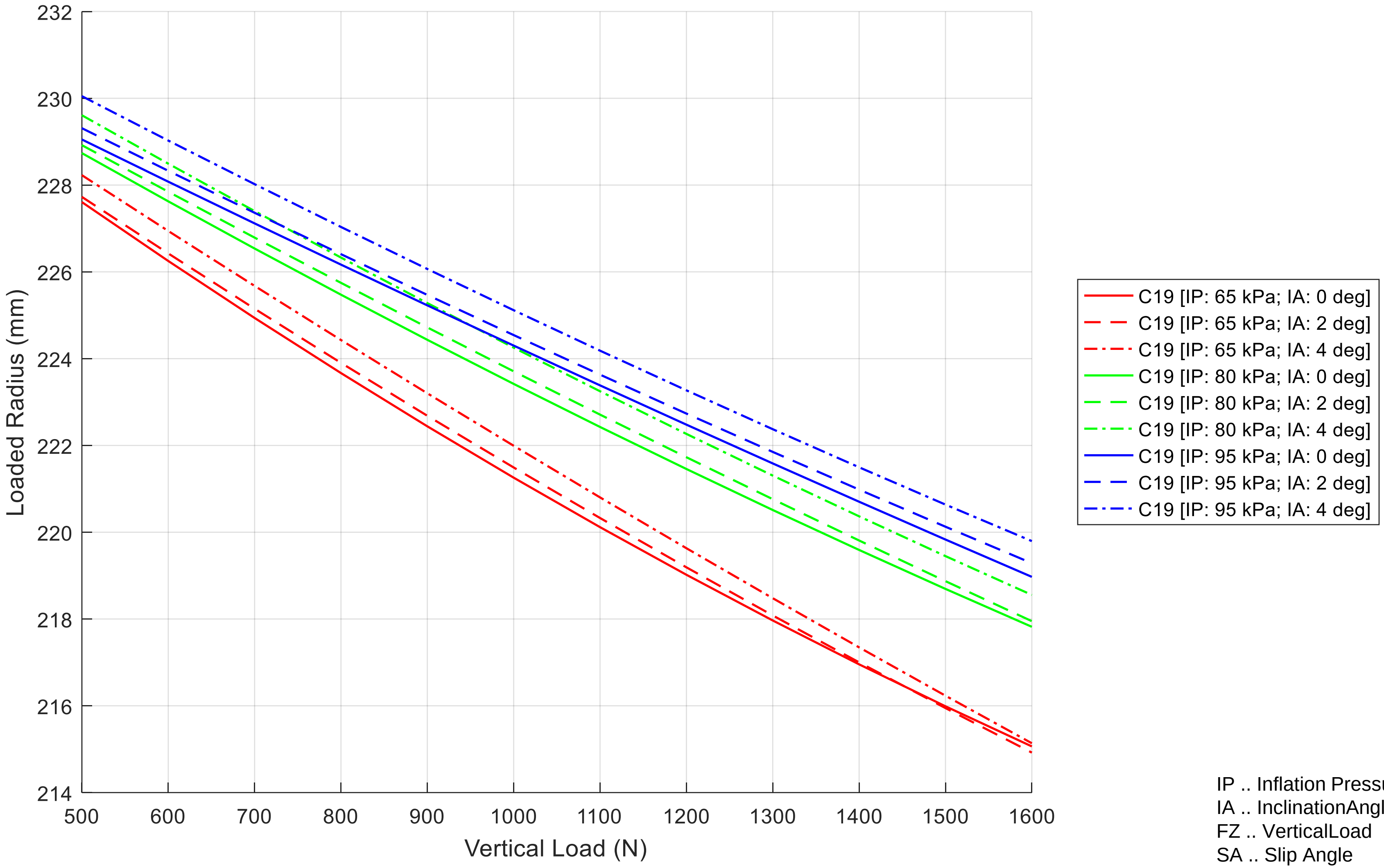
Sincerely,

Your Continental Team

Contents

1. Vertical Stiffness & Loaded Radius

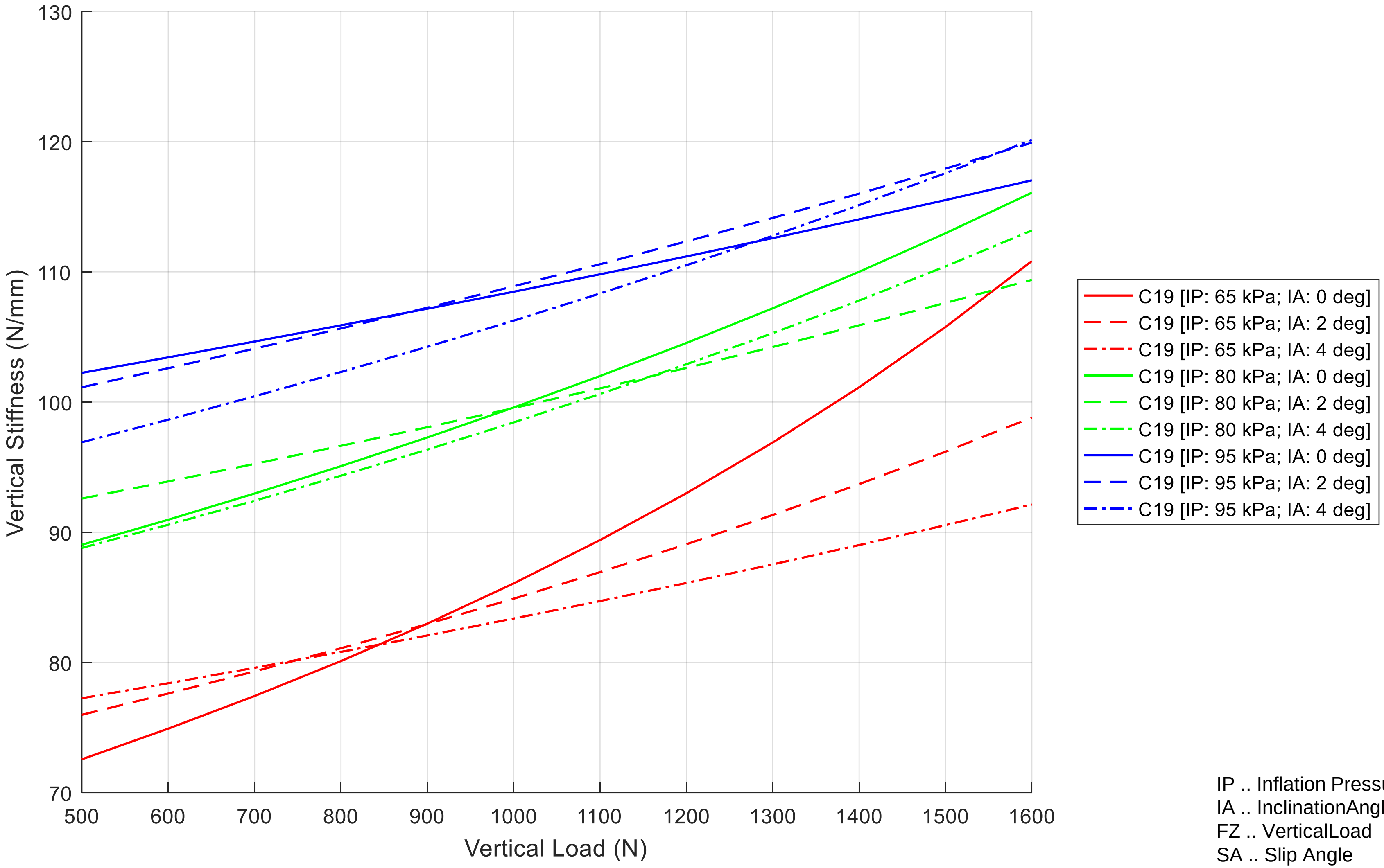
Loaded Radius



IP .. Inflation Pressure
IA .. InclinationAngle
FZ .. VerticalLoad
SA .. Slip Angle
SR .. Slip Ratio

1. Vertical Stiffness & Loaded Radius

Vertical Stiffness



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2. MF-Tyre 5.2 – Tire Property File (*.tir)

The force & moment characteristics of the C19 are represented by the Pacejka MF-Tyre 5.2 model. The according tire model coefficients for the pure lateral slip conditions have been fitted to measurement data from a Flat Trac test machine in order to:

› get representations of the raw data without noise & hysteresis effects from the measurement

› be able to reasonably interpolate/extrapolate between/beyond the measured test conditions

› obtain further representations like derivatives (e.g. cornering stiffness) or normalized values, extreme values etc. (e.g. coefficient of friction)

› have a mathematical representation of the tire F&M characteristics to be used for vehicle dynamics simulations etc.

2. MF-Tyre 5.2 – Tire Property File (*.tir)

The Pacejka MF-Tyre 5.2 model coefficients that were identified by the fitting of the raw data are stored in a Tire Property File. This file can be used by vehicle dynamic simulation software. It is also possible to extract the coefficients manually or by a custom made software routine.

The Tire Property Files for the C19 slick tire that come along with this document are named as follows:

“C19_CONTINENTAL_FORMULASTUDENT_205_470_R13_65kPa.tir”

“C19_CONTINENTAL_FORMULASTUDENT_205_470_R13_80kPa.tir”

“C19_CONTINENTAL_FORMULASTUDENT_205_470_R13_95kPa.tir”

For further information on the Pacejka MF-Tyre 5.2 model please refer to the common literature.

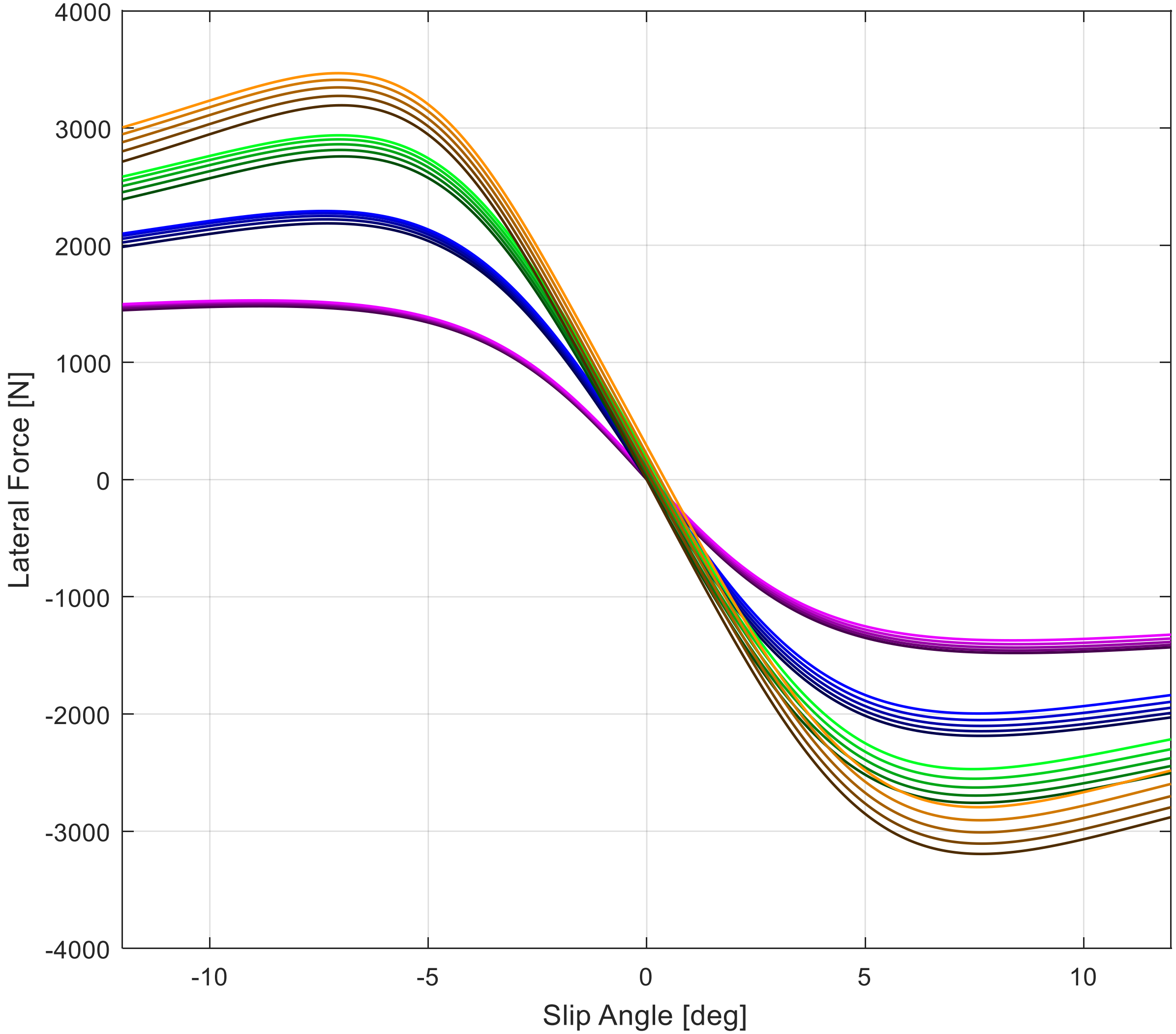
3. MF-Tyre 5.2 Plot – Lateral Slip

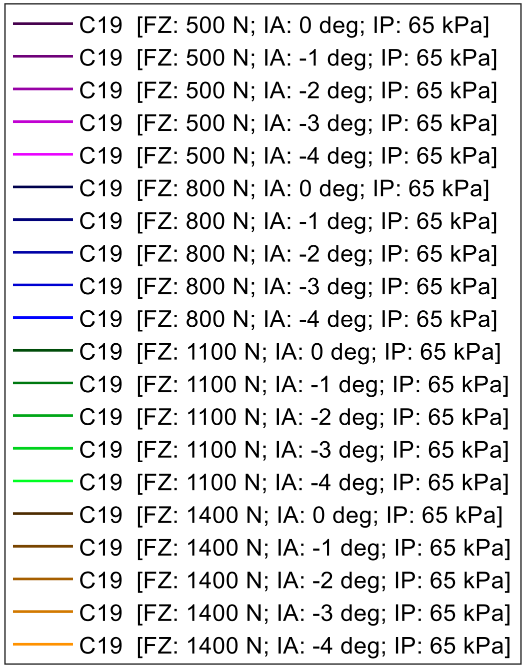
On the next pages, the MF-Tyre 5.2 model outputs will be plotted for the coefficients from the C19 Tire Property Files.

3. MF-Tyre 5.2 Plot – Lateral Slip

Lateral Force

65 kPA





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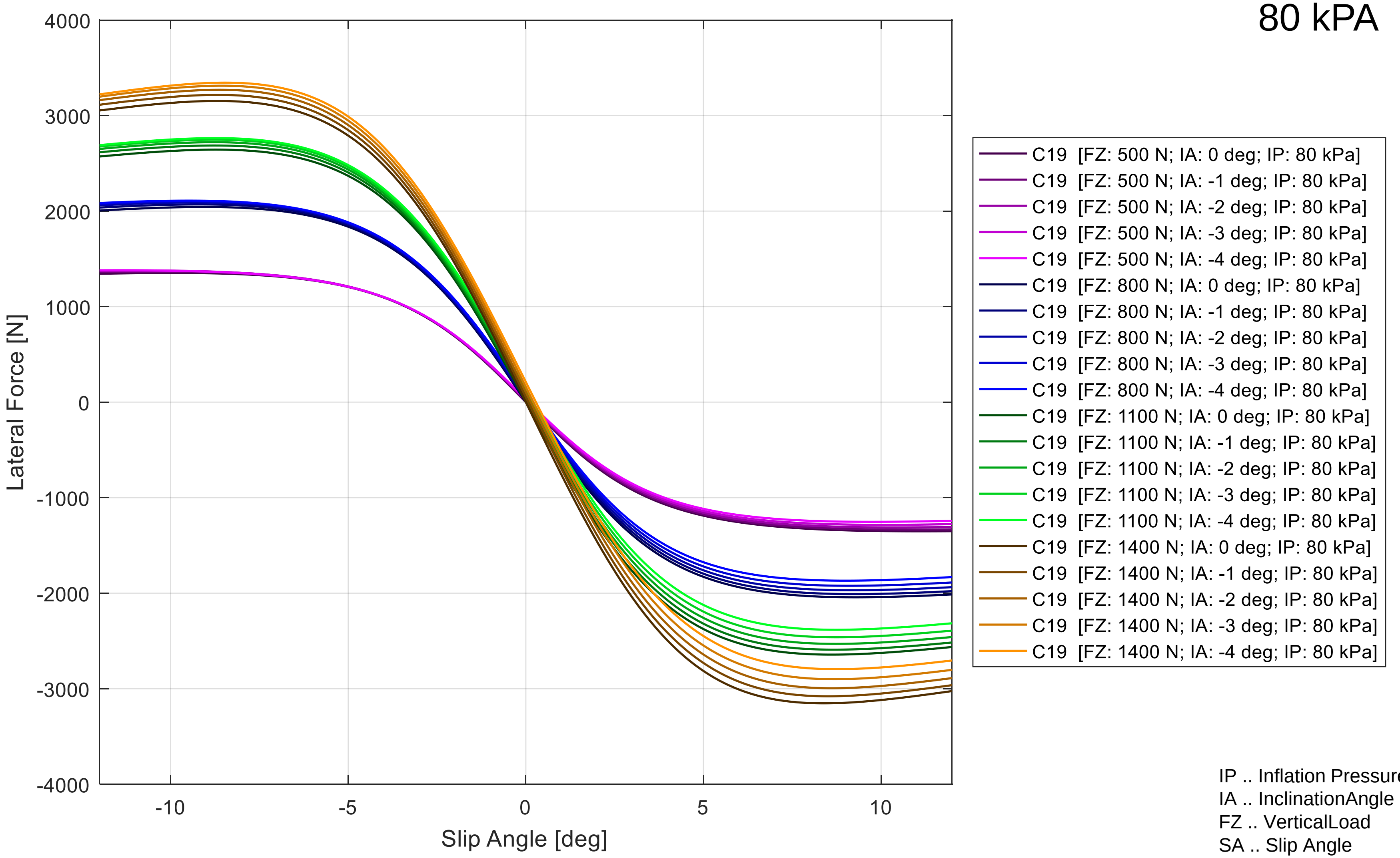
3. MF-Tyre 5.2 Plot – Lateral Slip

Lateral Force

80 kPA



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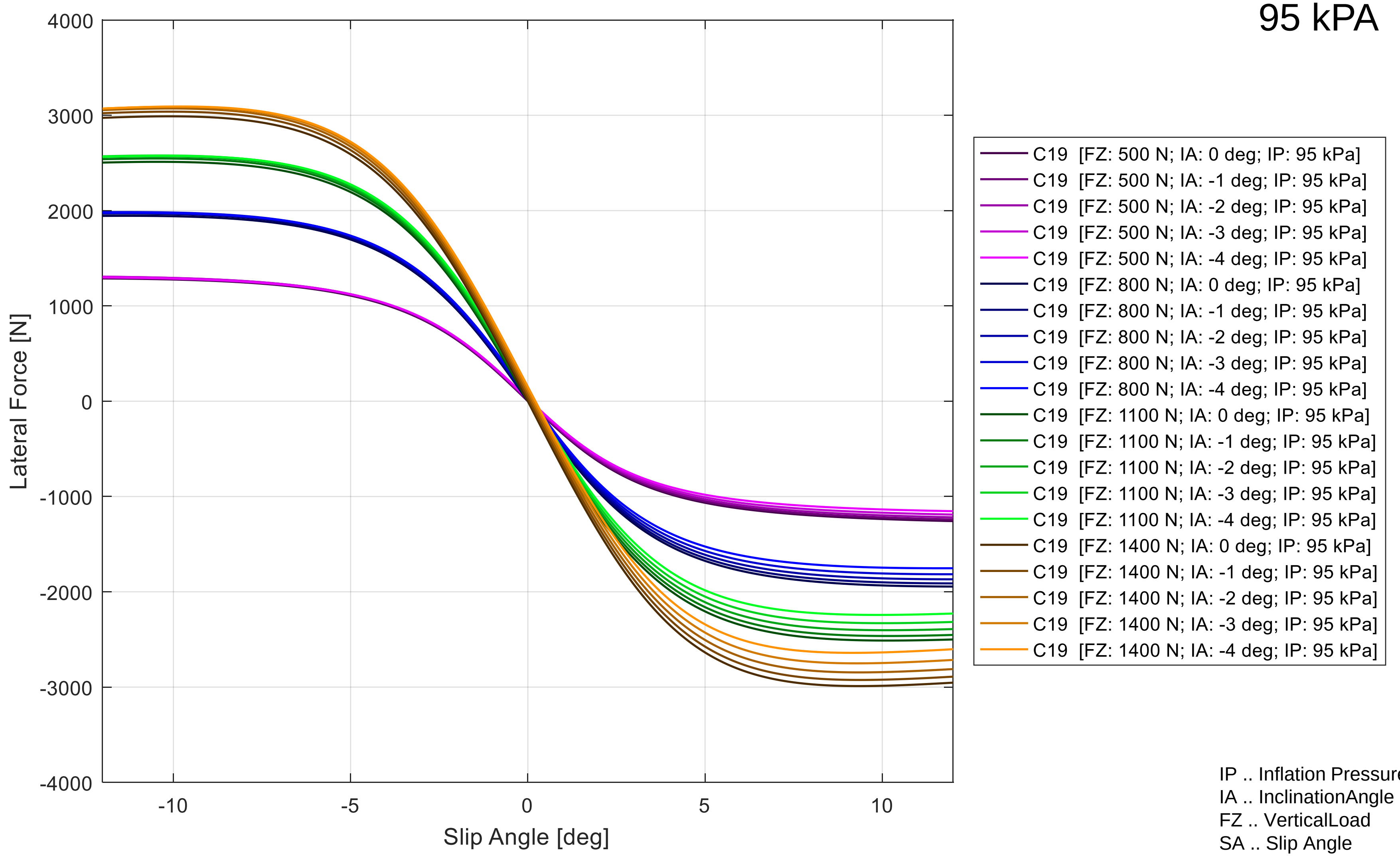
3. MF-Tyre 5.2 Plot – Lateral Slip

Lateral Force

95 kPA



IP .. Inflation Pressure
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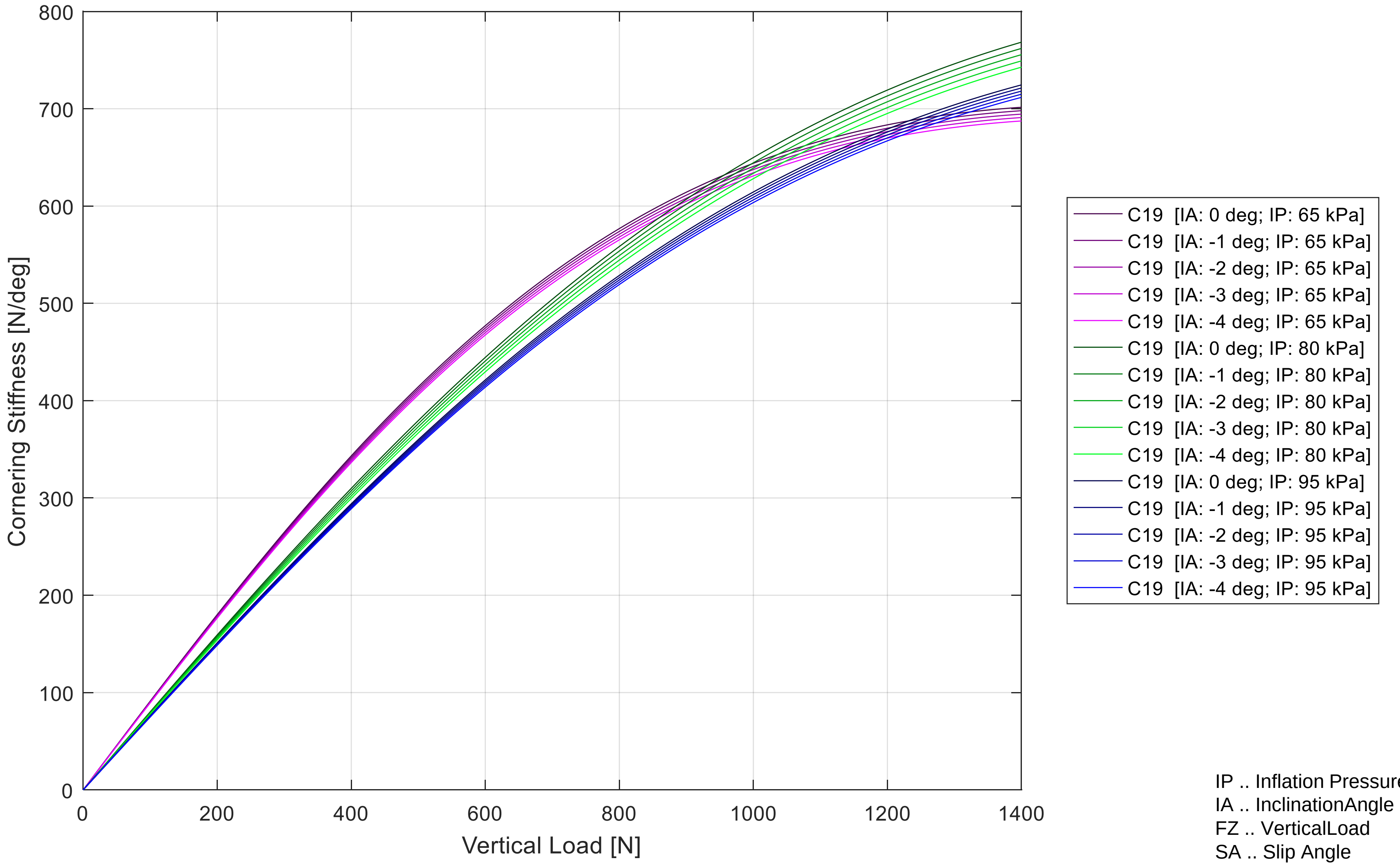
3. MF-Tyre 5.2 Plot – Lateral Slip

Cornering Stiffness



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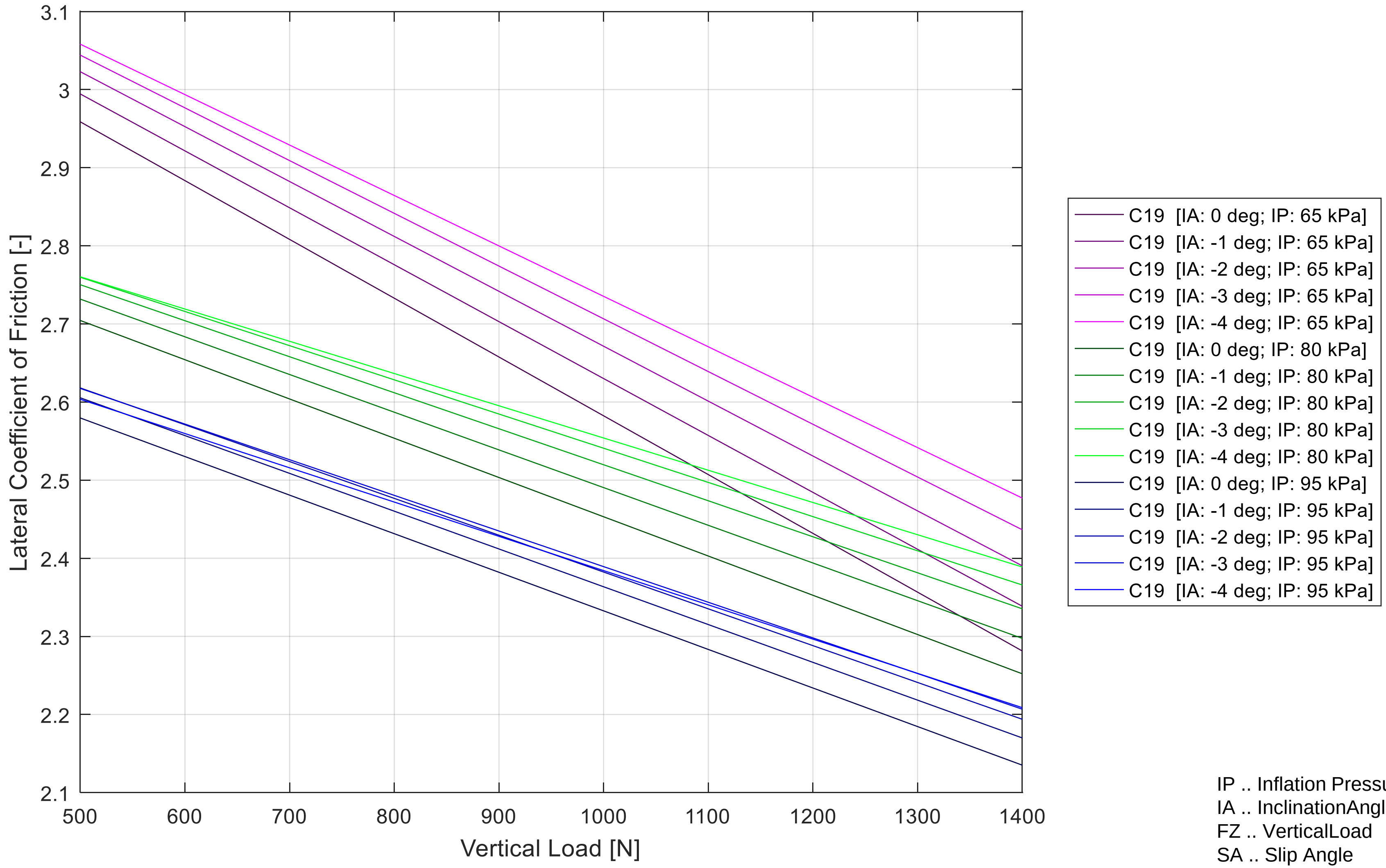
3. MF-Tyre 5.2 Plot – Lateral Slip

Lat. COF



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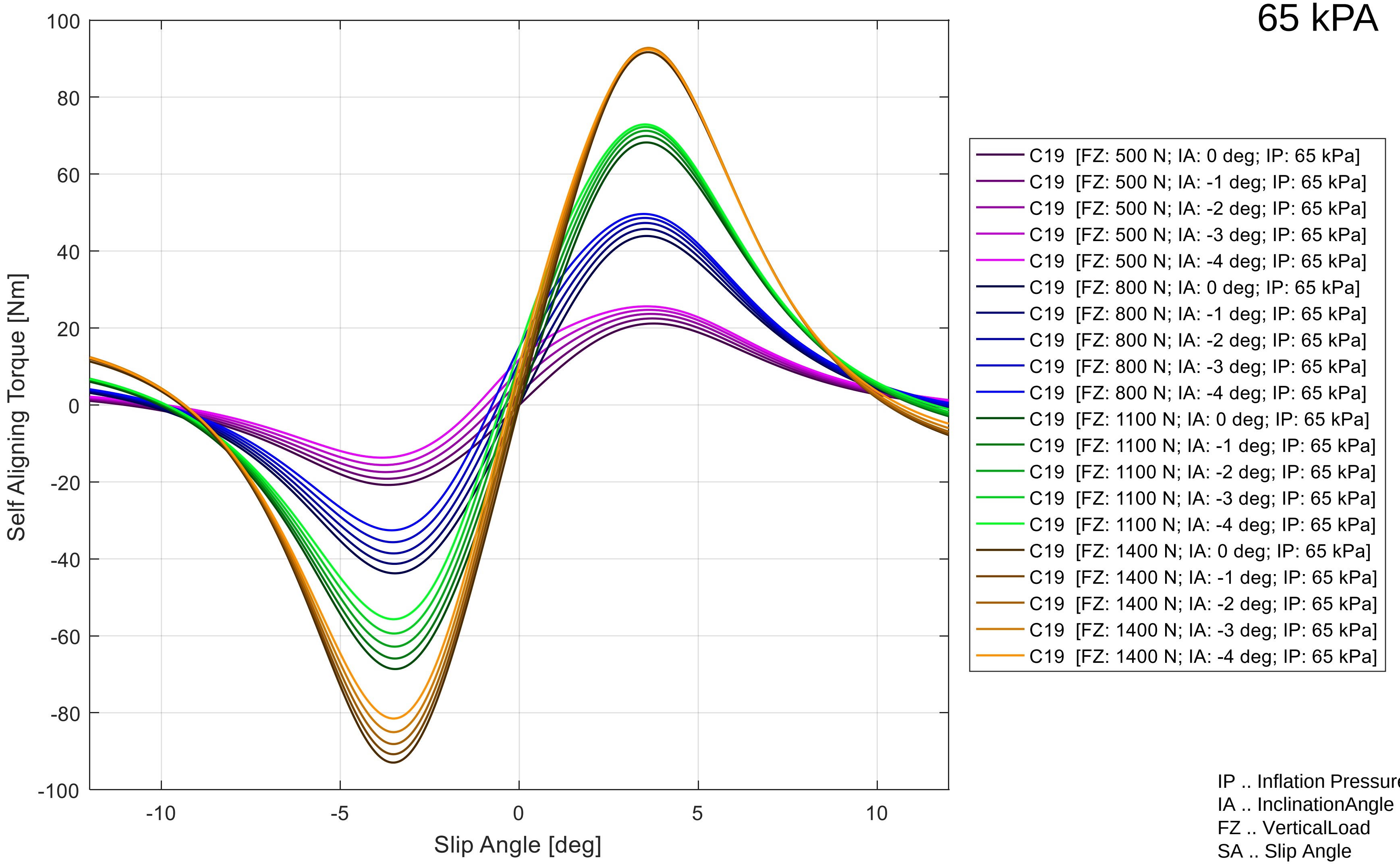
3. MF-Tyre 5.2 Plot – Lateral Slip

self aligning torque

65 kPA



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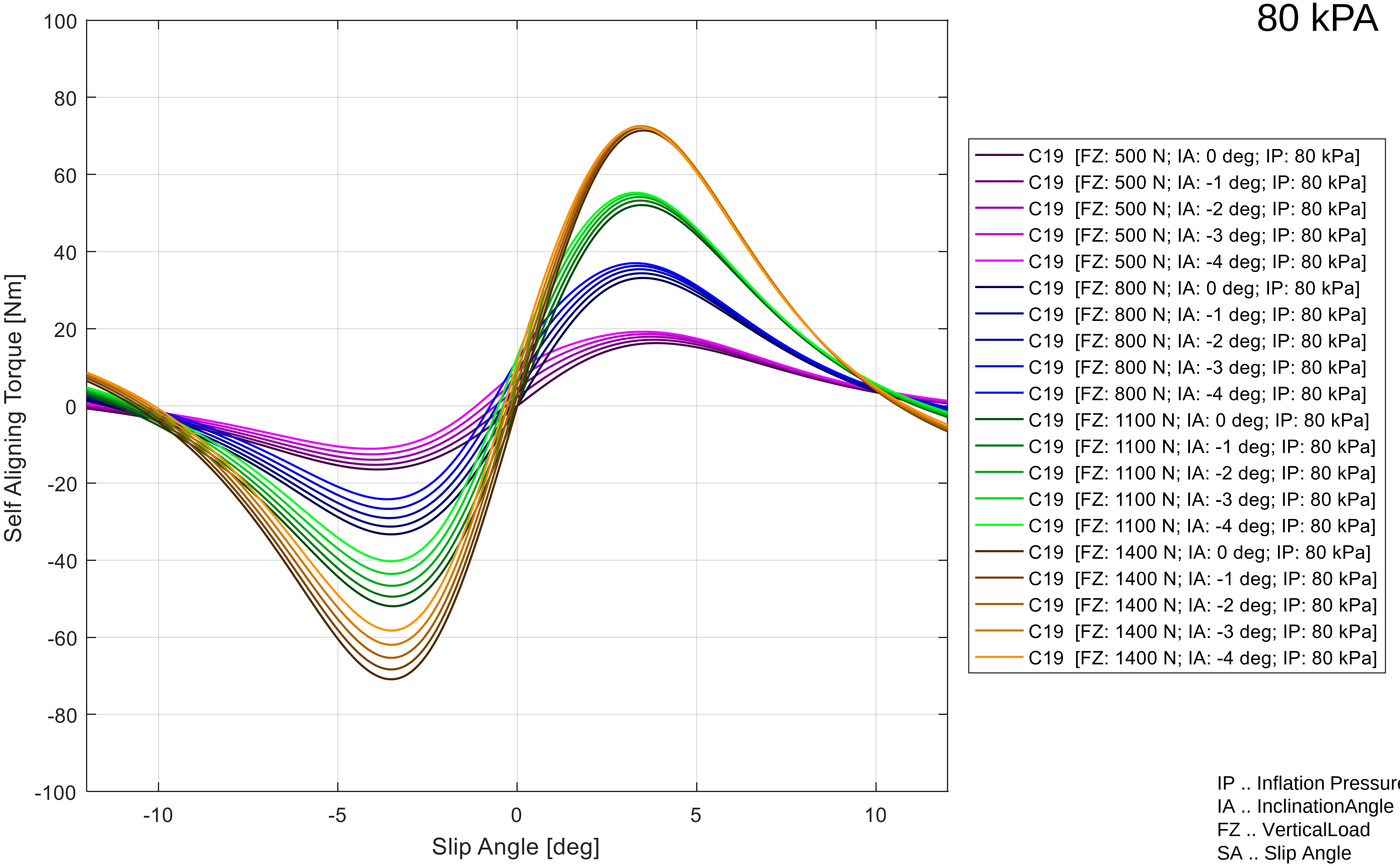
3. MF-Tyre 5.2 Plot – Lateral Slip

self aligning torque

80 kPA



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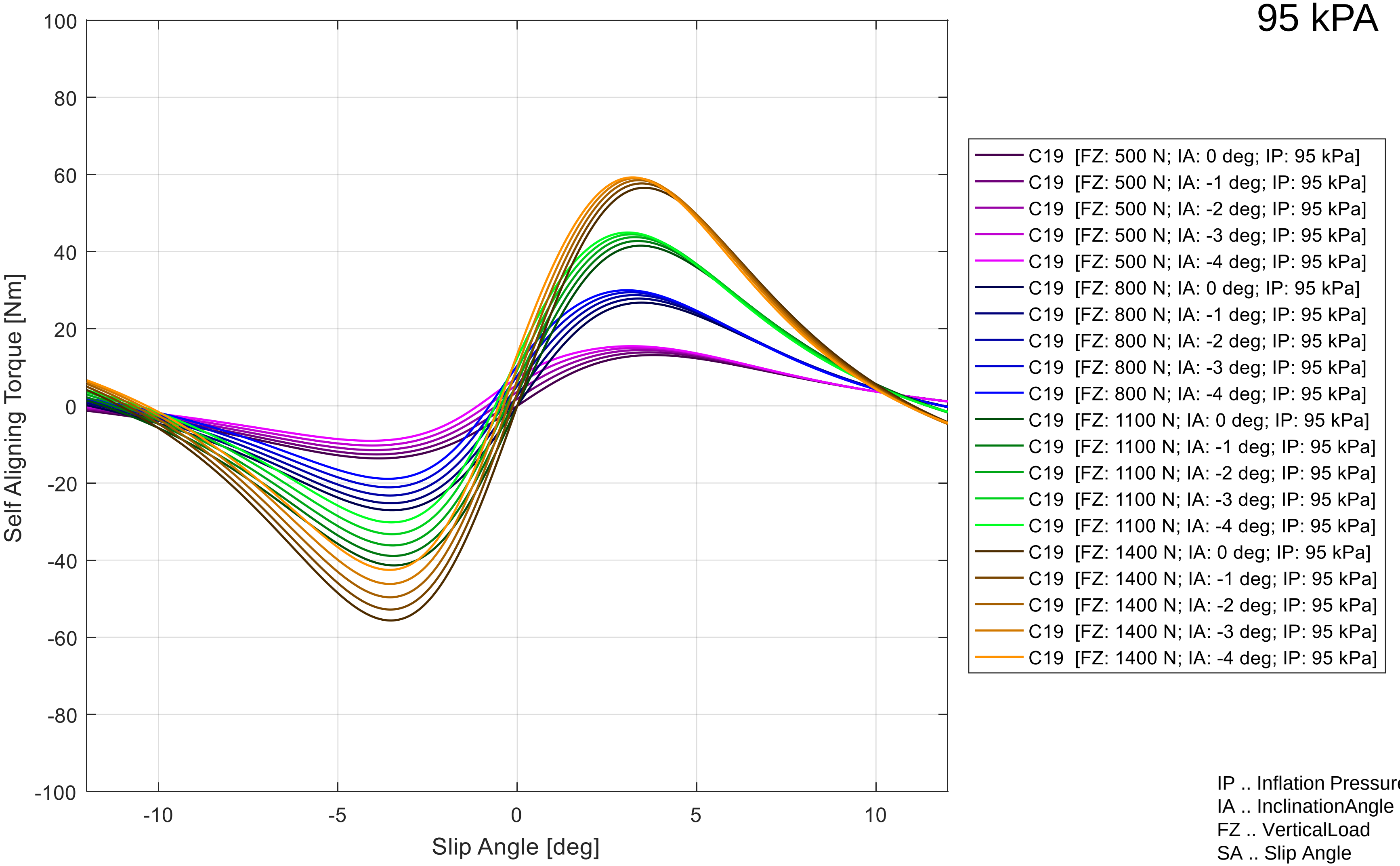
3. MF-Tyre 5.2 Plot – Lateral Slip

self aligning torque

95 kPA



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FZ .. VerticalLoad
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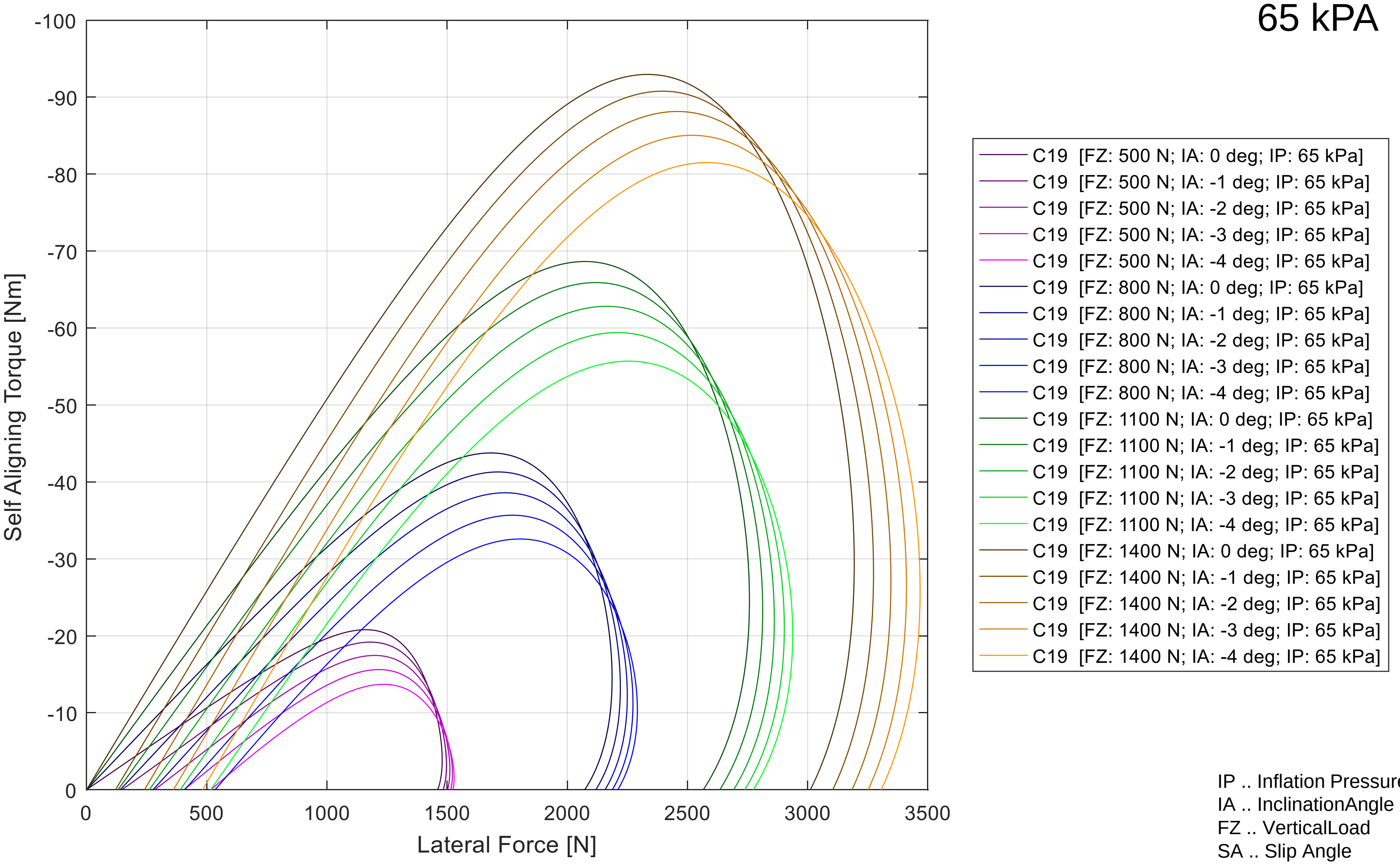
SR .. Slip Ratio

3. MF-Tyre 5.2 Plot – Lateral Slip

Gough plot

65 kPA



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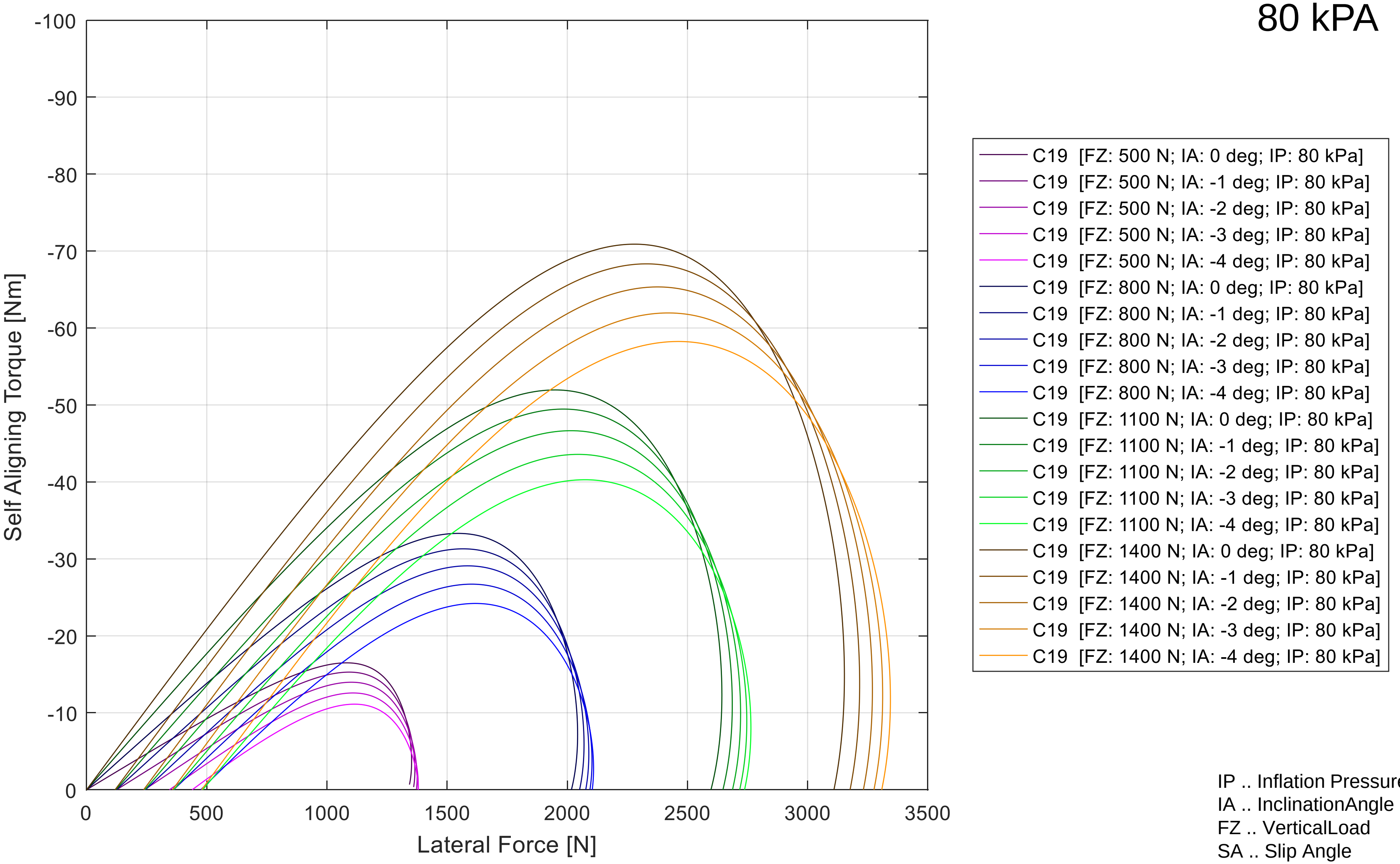
3. MF-Tyre 5.2 Plot – Lateral Slip

Gough plot

80 kPA



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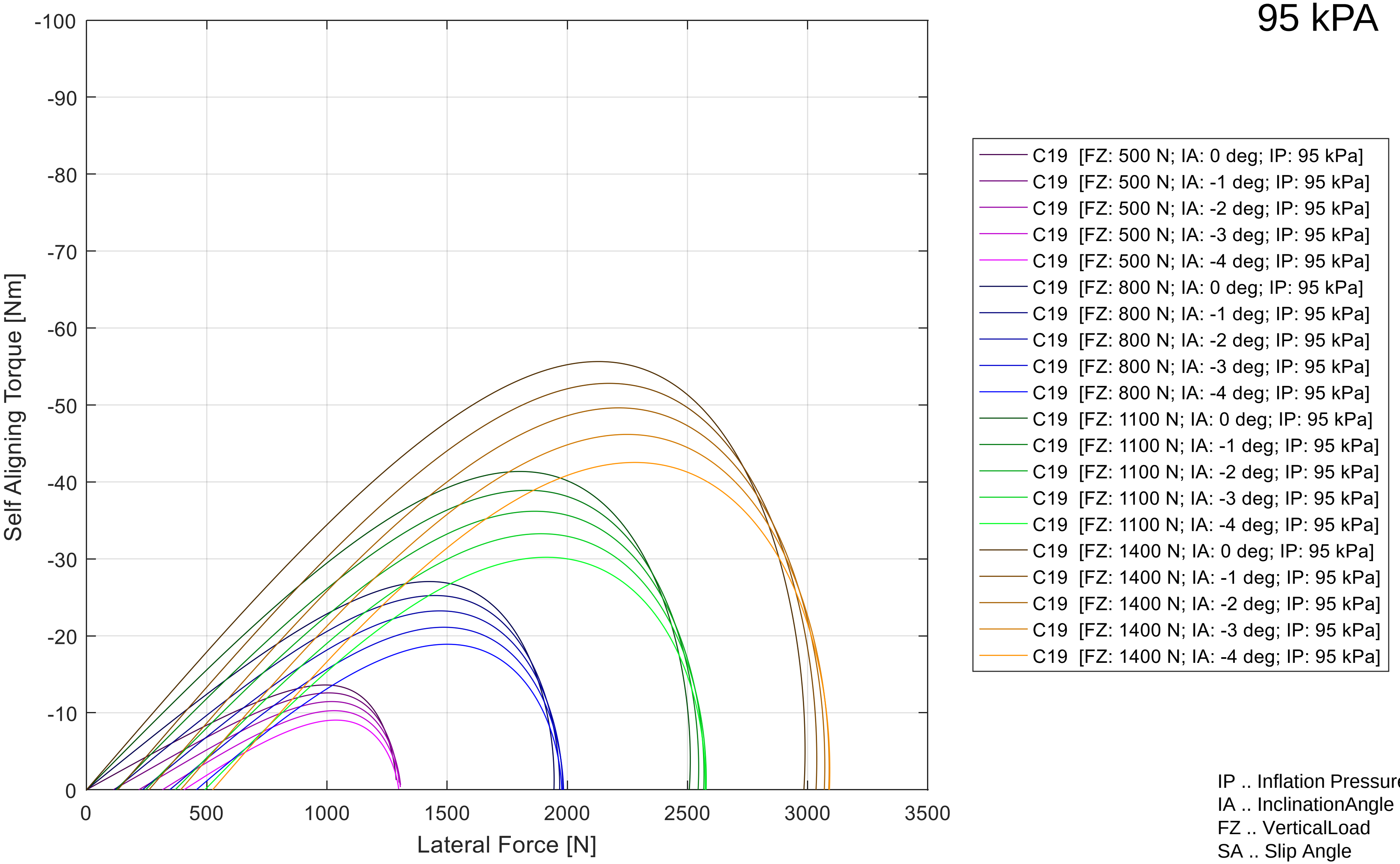
3. MF-Tyre 5.2 Plot – Lateral Slip

Gough plot

95 kPA



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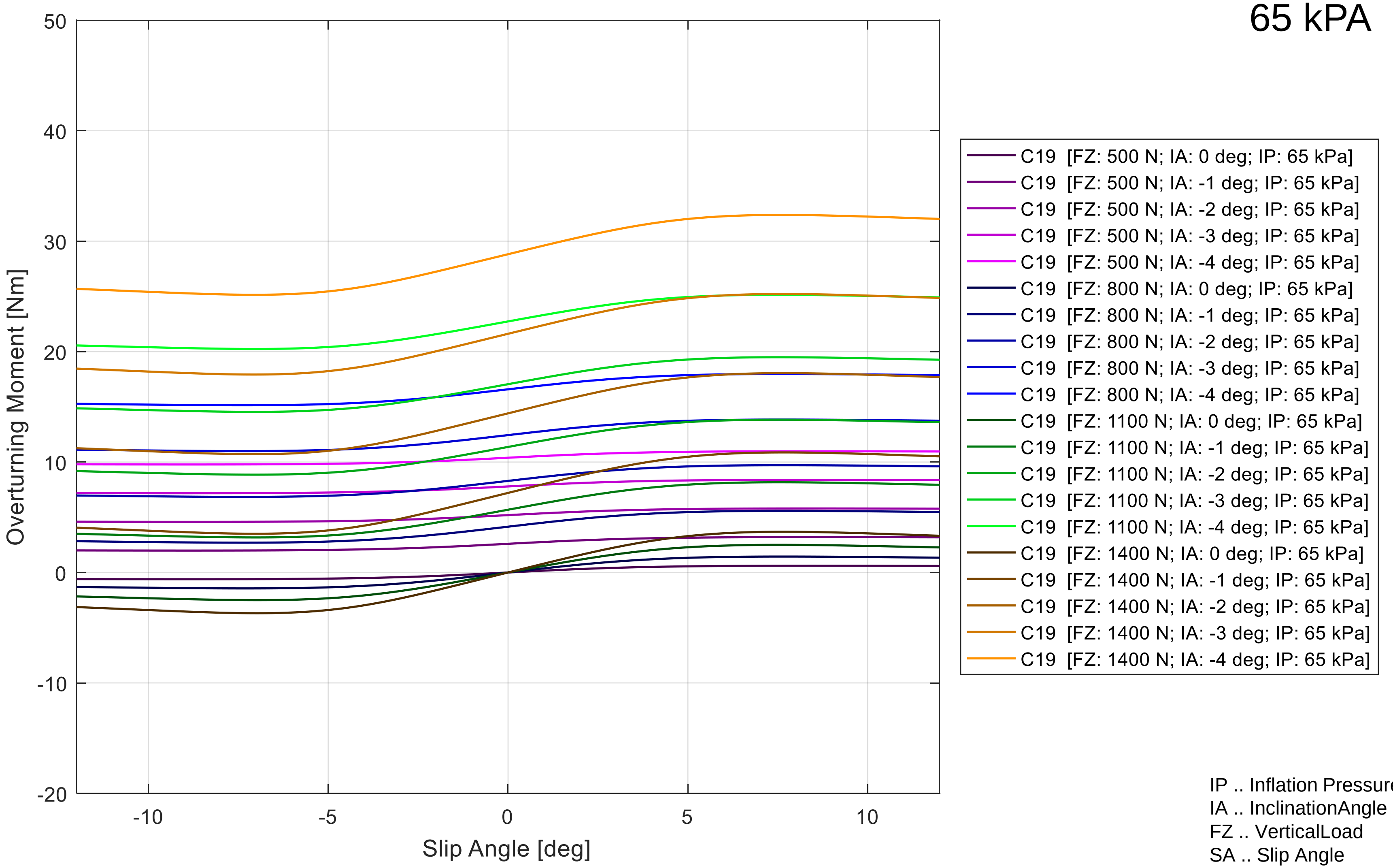
3. MF-Tyre 5.2 Plot – Lateral Slip

Overturning Moment

65 kPA



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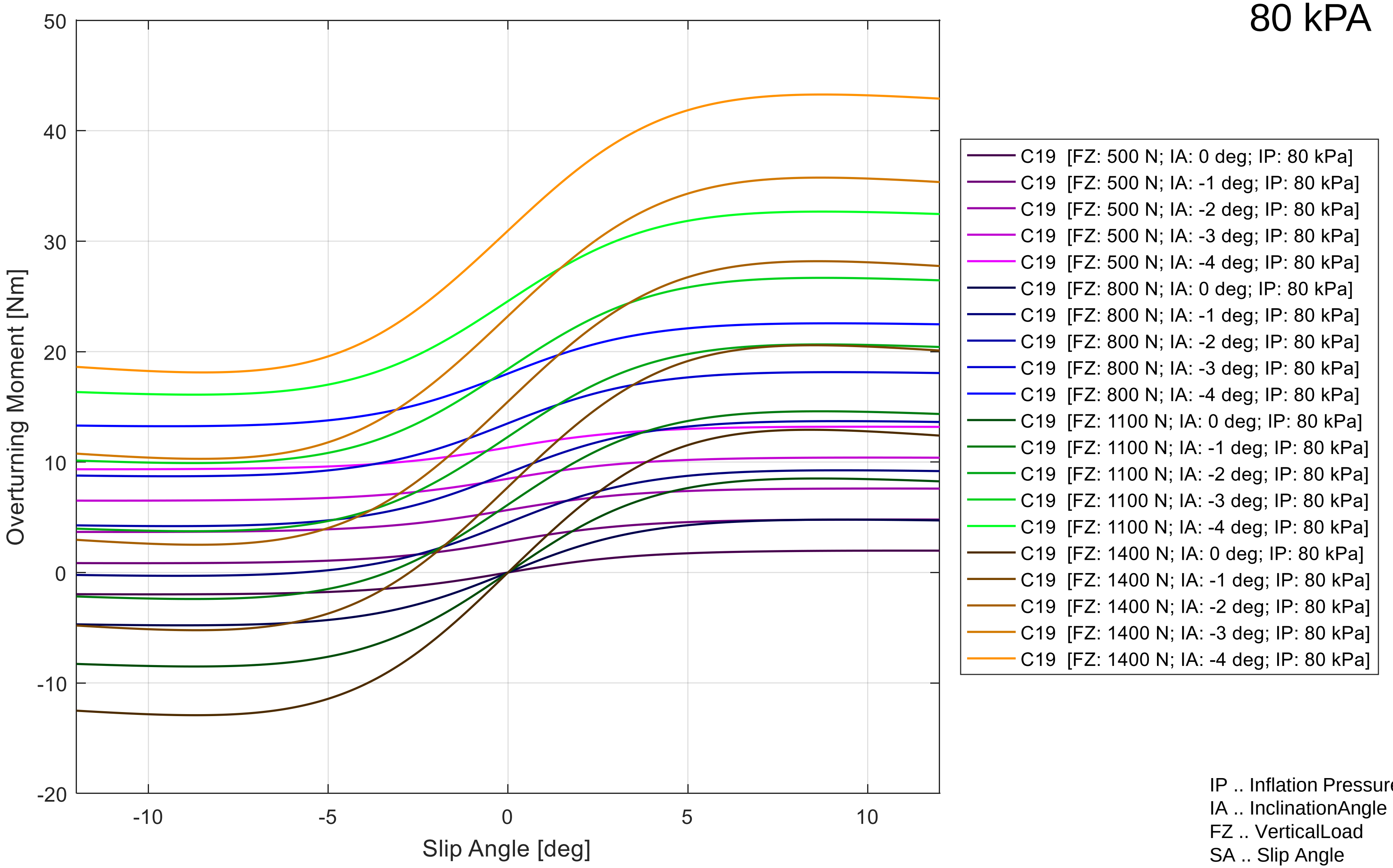
3. MF-Tyre 5.2 Plot – Lateral Slip

Overturning Moment

80 kPA



IP .. Inflation Pressure
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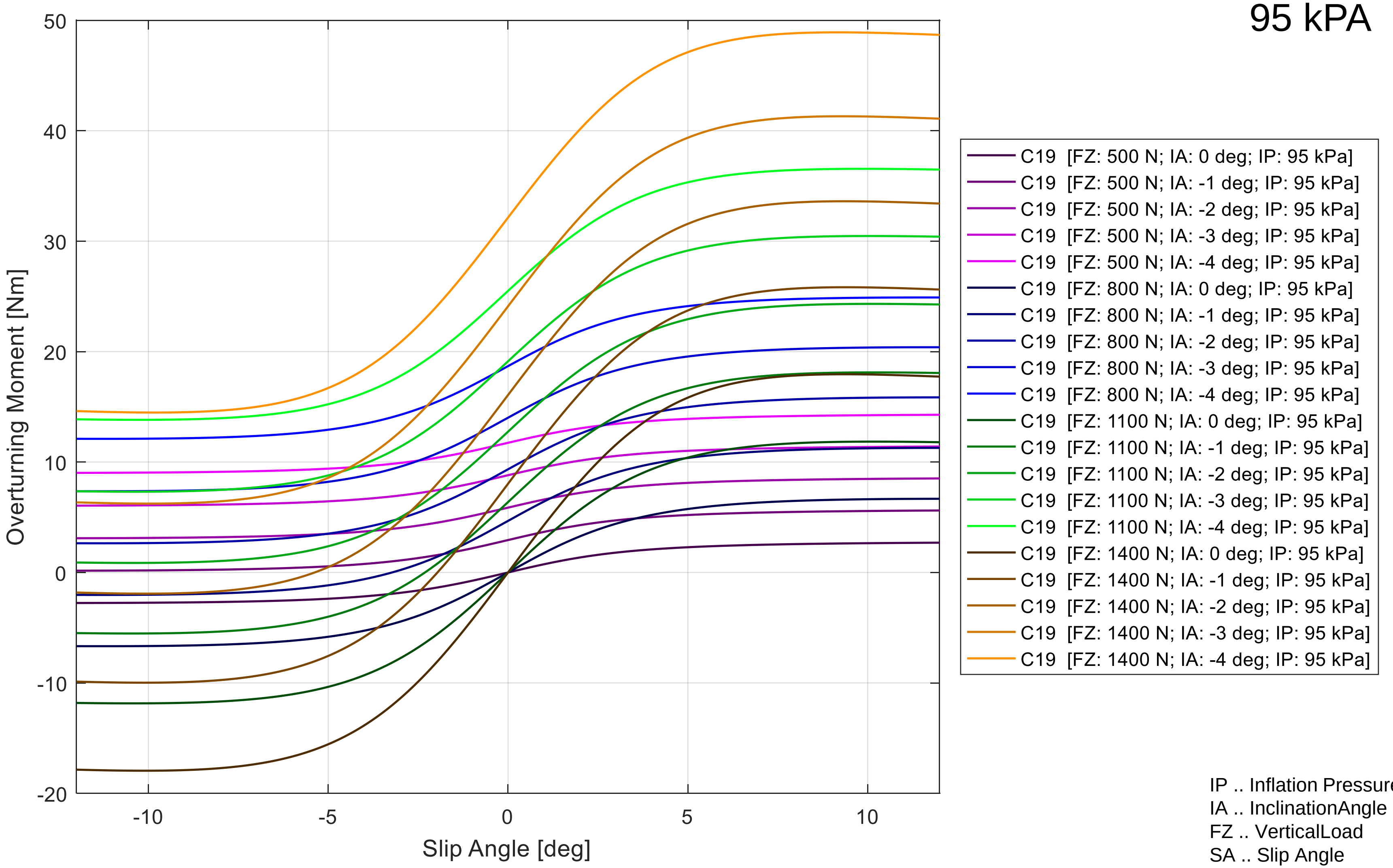
3. MF-Tyre 5.2 Plot – Lateral Slip

Overturning Moment

95 kPA



IP .. Inflation Pressure
IA .. InclinationAngle
FZ .. VerticalLoad
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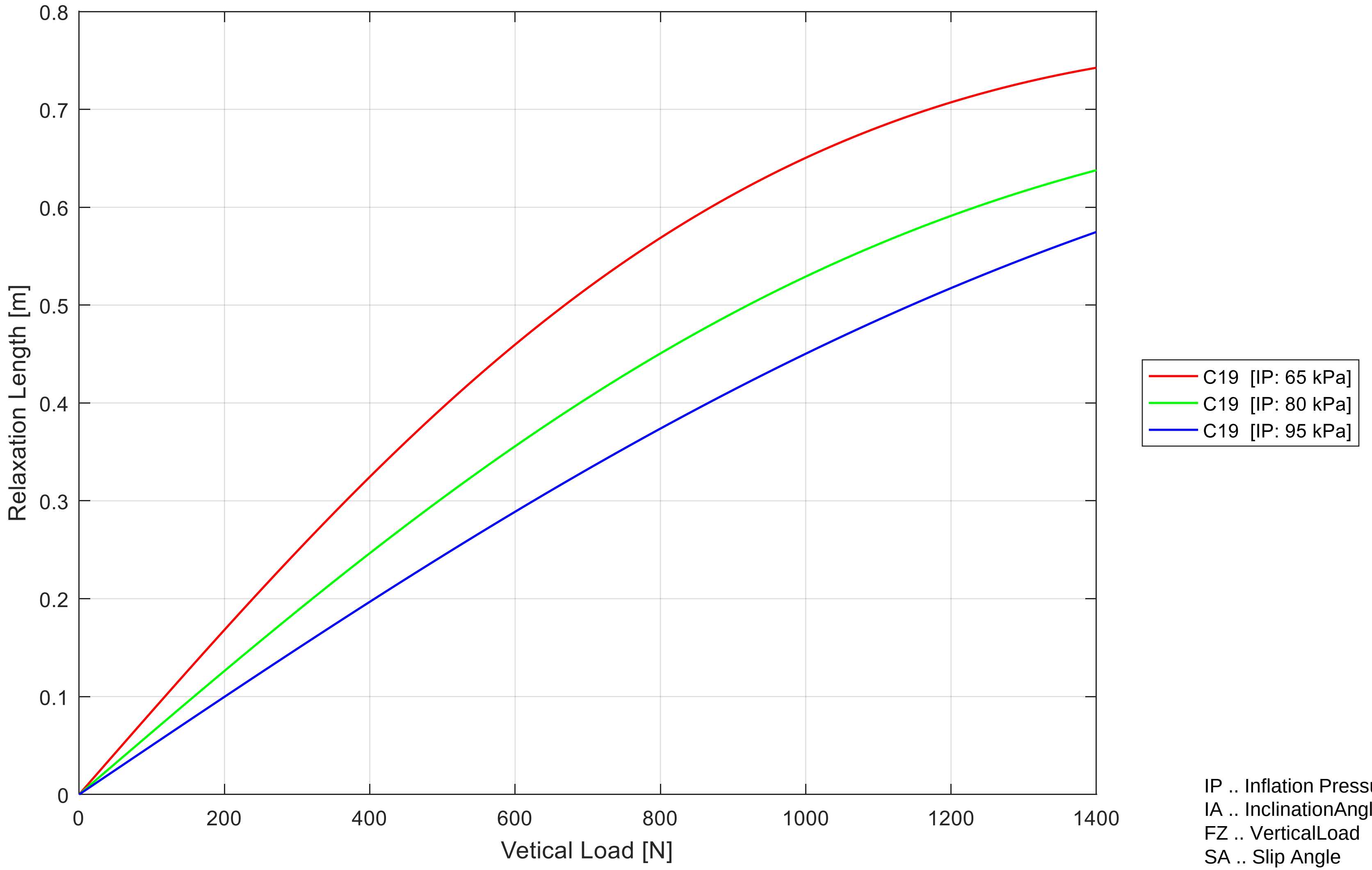
3. MF-Tyre 5.2 Plot – Lateral Slip

Relaxation Length



IP .. Inflation Pressure
IA .. InclinationAngle
FZ .. VerticalLoad
SA .. Slip Angle
SR .. Slip Ratio

4. MF-Tyre 5.2 Plot – Longitudinal Slip

It should be noted that the MF-Tyre 5.2 Tire Property Files for the C19 contain coefficients for the longitudinal and combined slip conditions that are actually **not** fitted to measured raw data from the Flat Trac.

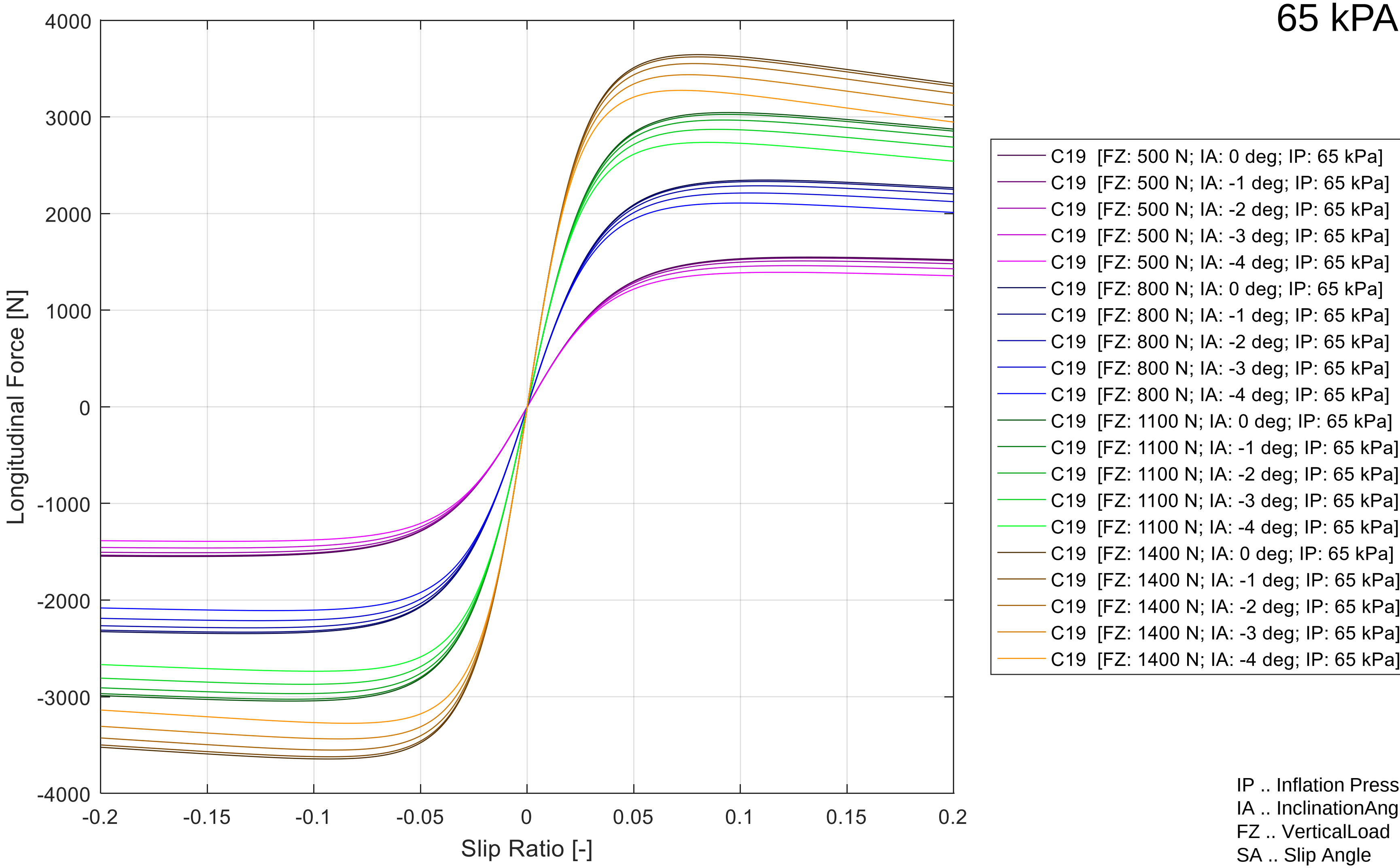
Instead, the longitudinal and combined models were designed based on experience and reference test data.

The model outputs for longitudinal and combined slip should be used with engineering judgement accordingly.

On the next pages, some model outputs for longitudinal slip are shown.

4. MF-Tyre 5.2 Plot – Longitudinal Slip Longitudinal Force

65 kPA



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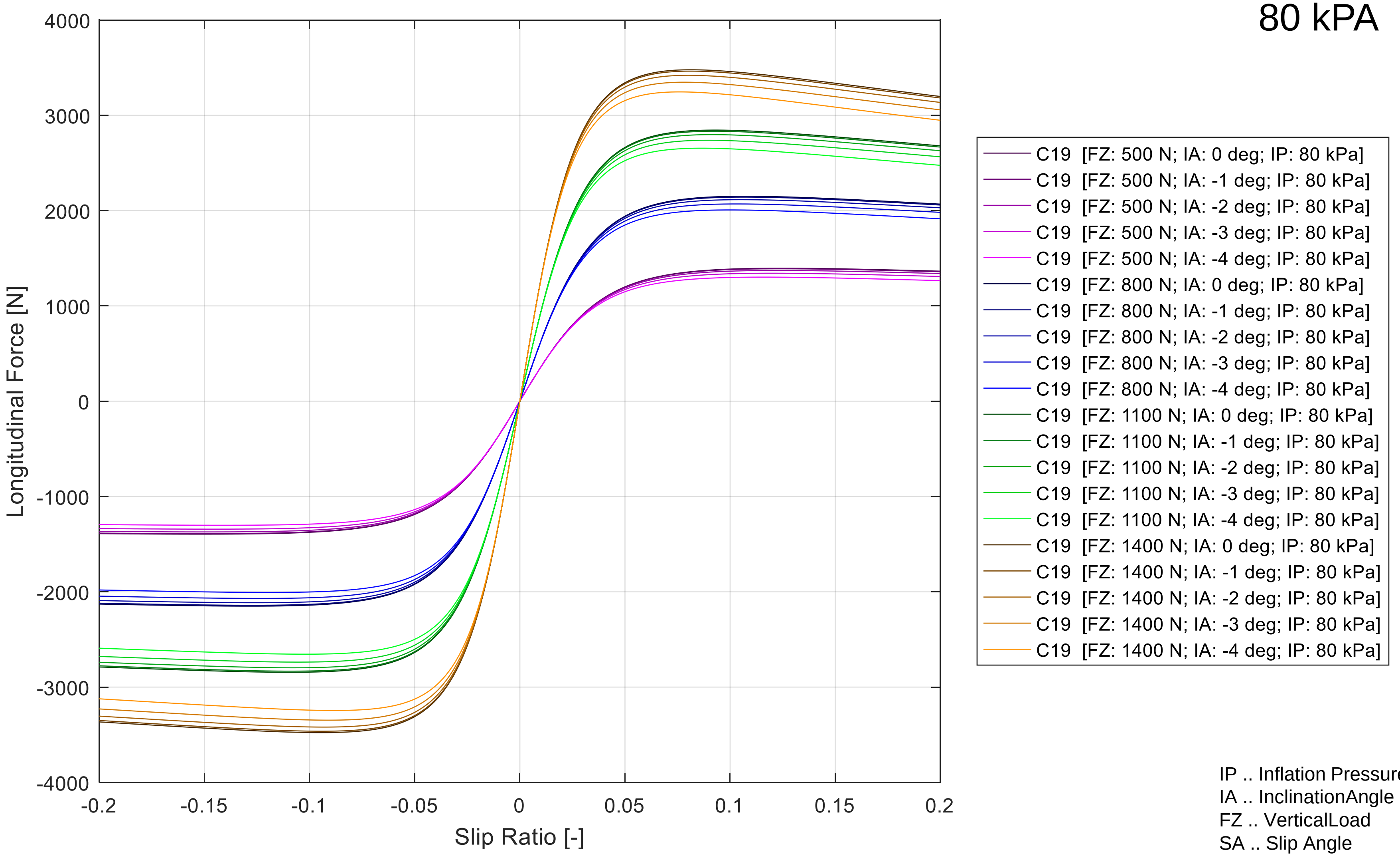
SR .. Slip Ratio

4. MF-Tyre 5.2 Plot – Longitudinal Slip Longitudinal Force

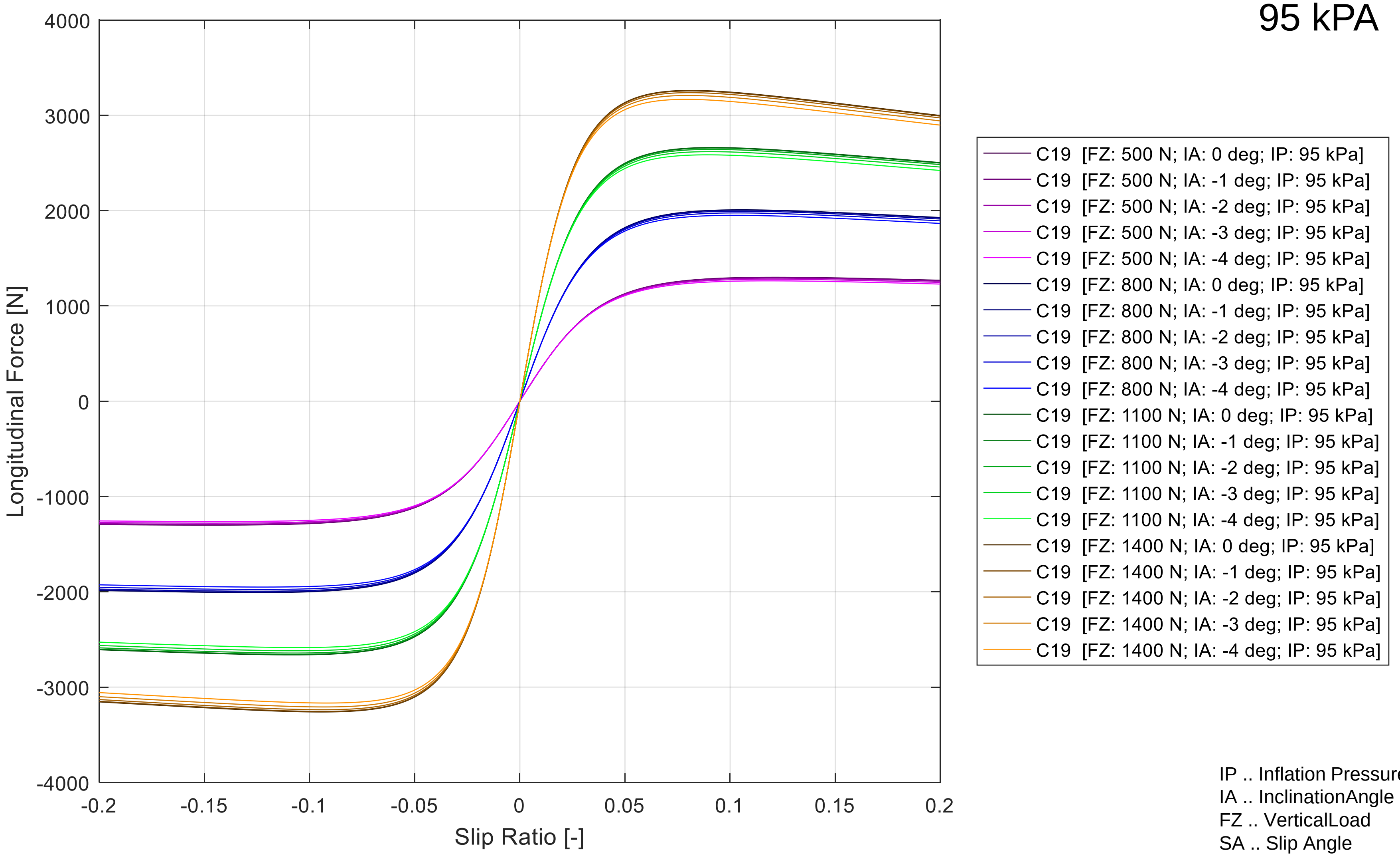
80 kPA



IP .. Inflation Pressure
IA .. InclinationAngle
FZ .. VerticalLoad
SA .. Slip Angle
SR .. Slip Ratio

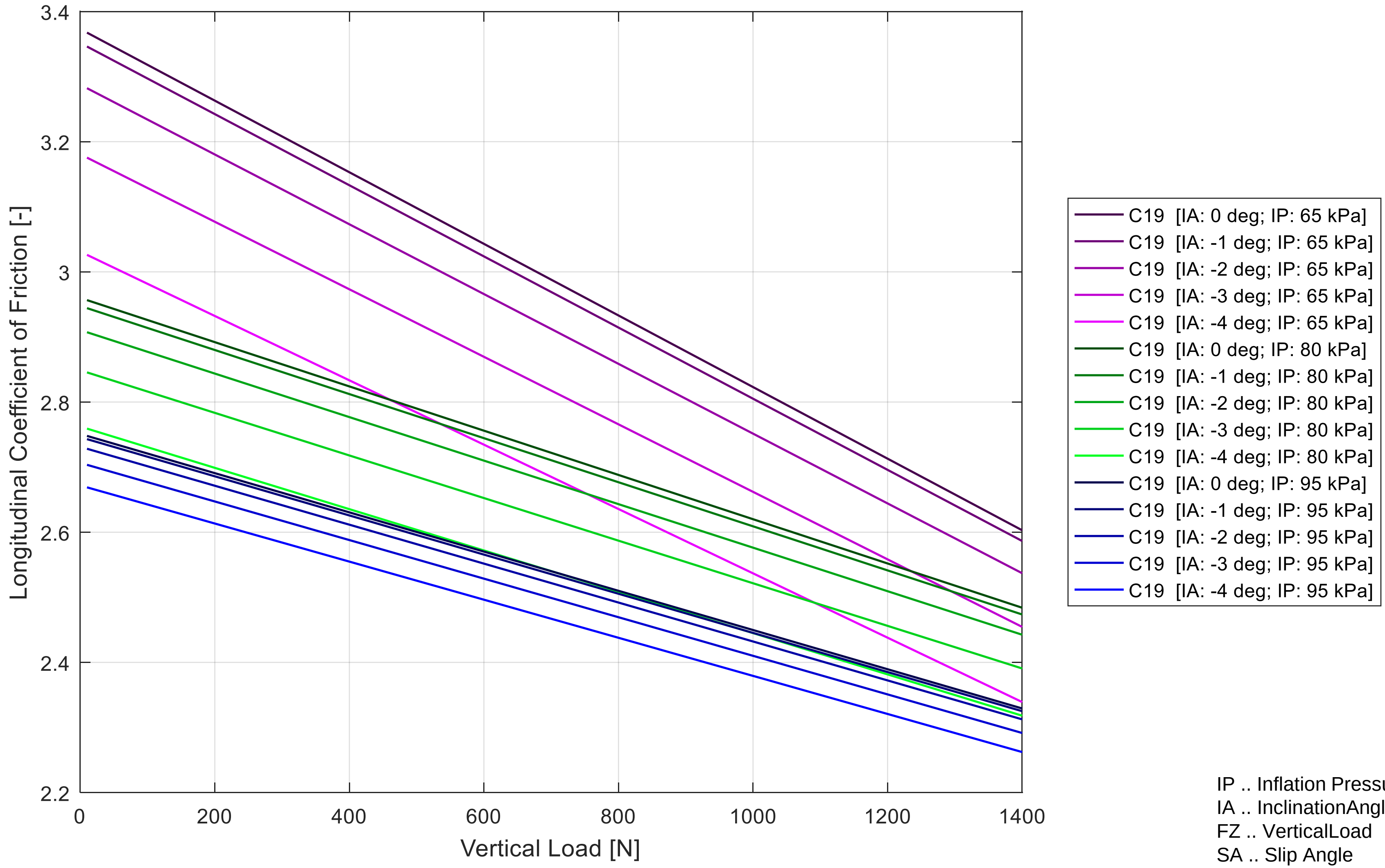
4. MF-Tyre 5.2 Plot – Longitudinal Slip   Longitudinal Force

95 kPA



IP .. Inflation Pressure
IA .. InclinationAngle
FZ .. VerticalLoad
SA .. Slip Angle
SR .. Slip Ratio

4. MF-Tyre 5.2 Plot – Longitudinal Slip Longitudinal COF



IP .. Inflation Pressure
IA .. InclinationAngle
FZ .. VerticalLoad
SA .. Slip Angle
SR .. Slip Ratio

5.1 Tire Model Guide – Model Limitations

The created tire models are valid within the given boundaries.

Parameter	min. Value	max. Value
Normal Load Range	230 N	1600 N
Long. Slip Range	-25 %	+25 %
Slip Angle Range	-12 °	+12 °
Inclination Angle Range	-6 °	+6 °

If needed, the boundaries can be edited in the *.tir-files.

It should be noted, that if the model parameters are increased beyond the boundaries the results can become unreasonable. Therefore, the model outputs should be checked carefully when leaving the given boundaries.

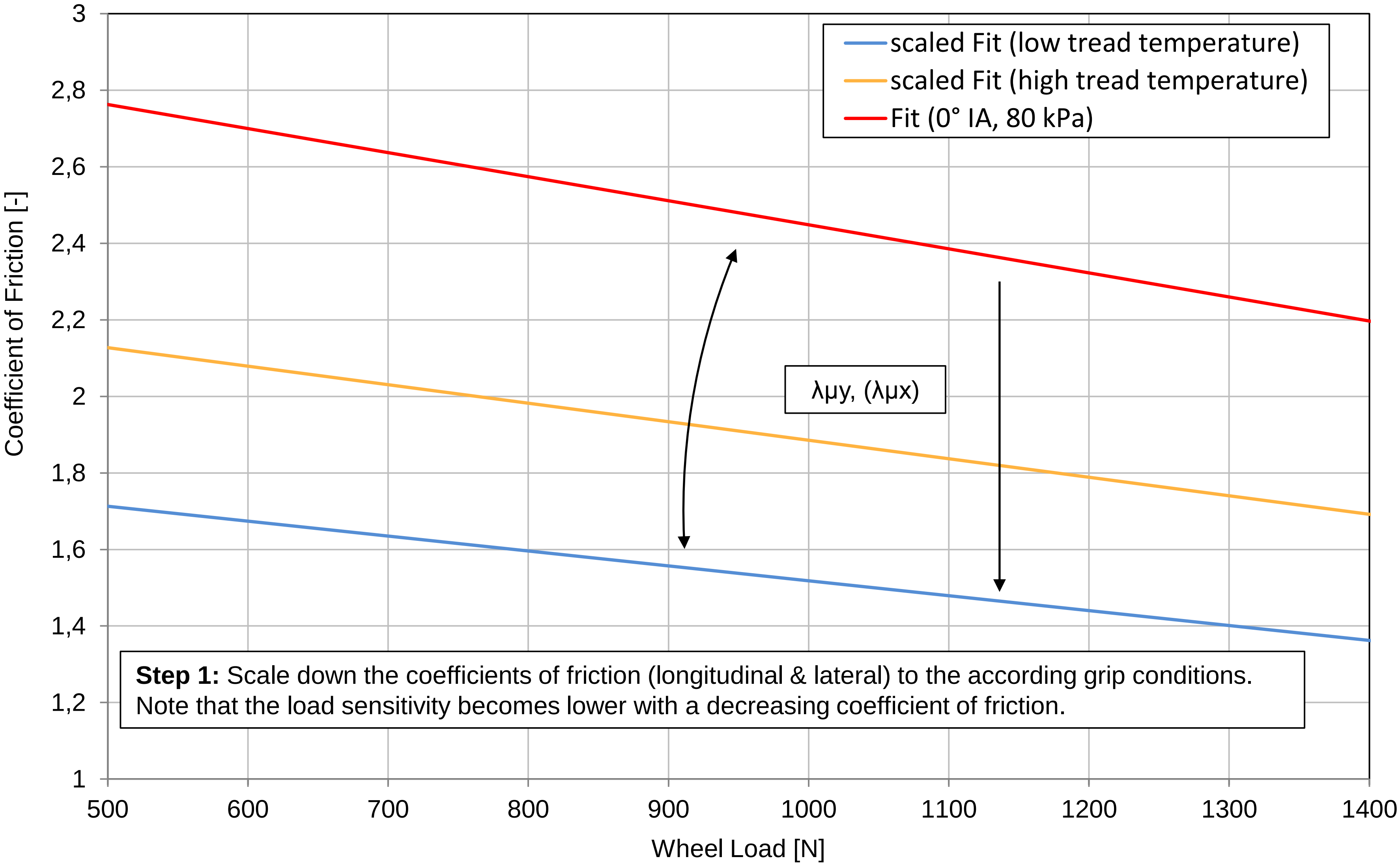
5.2 Tire Model Guide – Scaling Factors

Using the provided tire model for vehicle dynamic simulations, it is possible to investigate trends and analyze target conflicts to find preferred vehicle configurations for the different dynamic events.

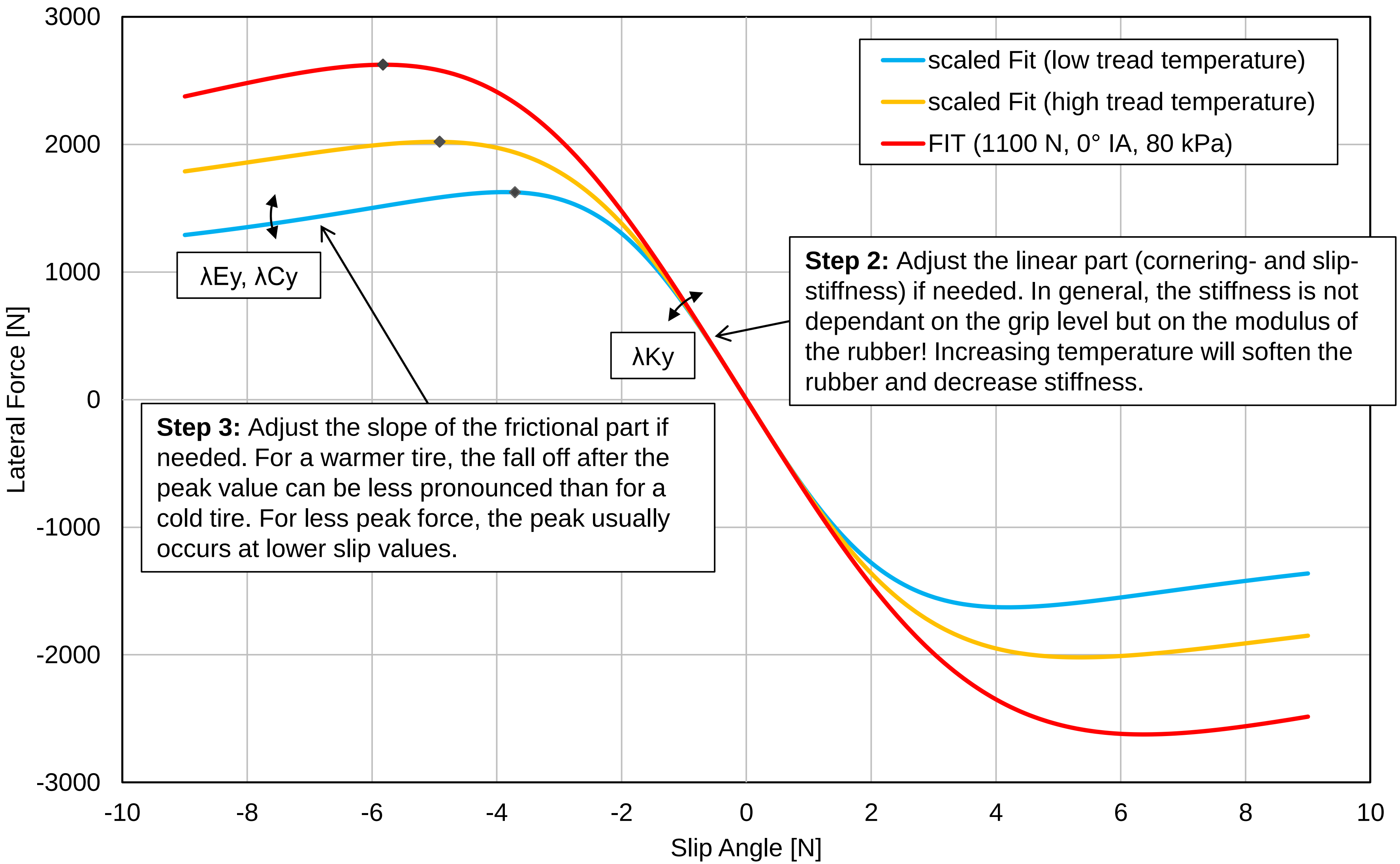
However, looking at the coefficients of friction it becomes obvious, that absolute assumptions have to be made very carefully. The tire grip on the Flat Trac is about 20% to 40% higher compared to typical Formula Student operating conditions. The differences in grip are mainly caused by the influences of the surface properties, i.e. micro-and macro-roughness as well as contaminations with dust, stones and other particles.

To have a more realistic simulation result, the tire model can be scaled down to appropriate grip conditions. Some explanations regarding the scaling of the model can be found on the following pages. Additionally, a set of exemplary scaling factors are provided as a starting point for further model scaling.

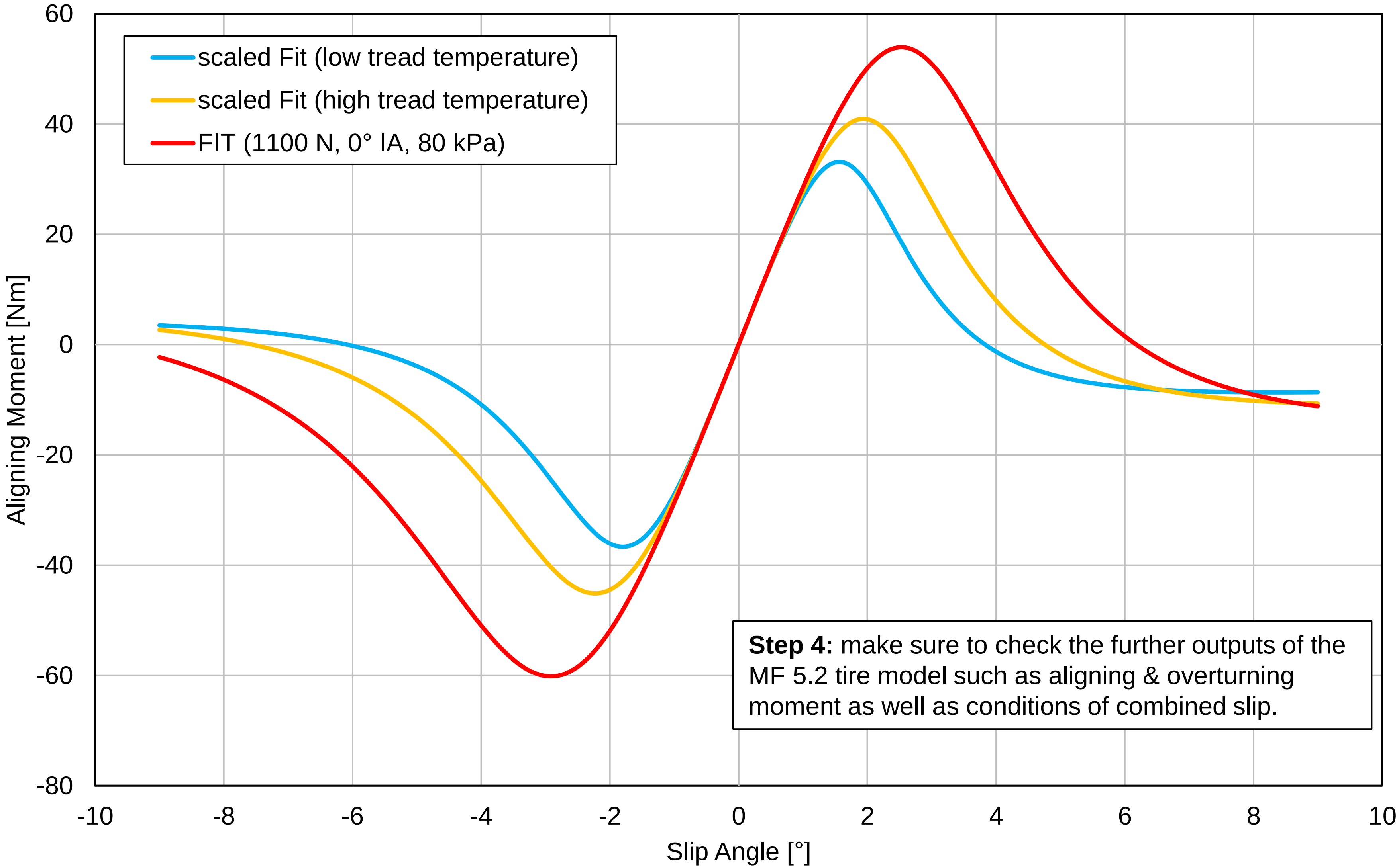
5.2 Tire Model Guide – Scaling Factors



5.2 Tire Model Guide – Scaling Factors



5.2 Tire Model Guide – Scaling Factors



Step 4: make sure to check the further outputs of the MF 5.2 tire model such as aligning & overturning moment as well as conditions of combined slip.

5.3 Tire Model Guide – Exemplary Scaling Factors

Exemplary Scaling Factors for Operating Tire Temperature

Name	Name used in tire property file	Standard Value	Exemplary Value	Explanation:
λFzo	LFZO	1	1	Scale factor of nominal (rated) load
λCx	LCX	1	1	Scale factor of Fx shape factor
λμx	LMUX	1	0.75	Scale factor of Fx peak friction coefficient
λEx	LEX	1	1	Scale factor of Fx curvature factor
λKx	LKX	1	1	Scale factor of Fx slip stiffness
λHx	LHX	1	1	Scale factor of Fx horizontal shift
λVx	LVX	1	1	Scale factor of Fx vertical shift
λγx	LGAX	1	1	Scale factor of camber for Fx
λCy	LCY	1	0.90	Scale factor of Fy shape factor
λμy	LMUY	1	0.75	Scale factor of Fy peak friction coefficient
λEy	LEY	1	1	Scale factor of Fy curvature factor
λKy	LKY	1	1	Scale factor of Fy cornering stiffness
λHy	LHY	0	0	Scale factor of Fy horizontal shift
λVy	LVY	0	0	Scale factor of Fy vertical shift
λγy	LGAY	1	0.75	Scale factor of camber for Fy
λt	LTR	1	1	Scale factor of Peak of pneumatic trail
λMr	LRES	0	0	Scale factor for offset of residual torque
λγz	LGAZ	1	1	Scale factor of camber for Mz
λMx	LMX	1	1	Scale factor of overturning couple
λvMx	LVMX	0	0	Scale factor of Mx vertical shift
λMy	LMY	1	1	Scale factor of rolling resistance torque
λxα	LXAL	1	1.15	Scale factor of alpha influence on *Fx*
λyκ	LYKA	1	1.15	Scale factor of alpha influence on *Fy*
λ*Vyκ*	LVYKA	1	1	Scale factor of kappa induced *Fy*
λs	LS	1	1	Scale factor of Moment arm of *Fx*

5.3 Tire Model Guide – Exemplary Scaling Factors

Exemplary Scaling Factors for very low Tire Temperature

Name	Name used in tire property file	Standard Value	Exemplary Value	Explanation:
λFzo	LFZO	1	1	Scale factor of nominal (rated) load
λCx	LCX	1	1	Scale factor of Fx shape factor
λμx	LMUX	1	0.6	Scale factor of Fx peak friction coefficient
λEx	LEX	1	1	Scale factor of Fx curvature factor
λKx	LKX	1	1	Scale factor of Fx slip stiffness
λHx	LHX	1	1	Scale factor of Fx horizontal shift
λVx	LVX	1	1	Scale factor of Fx vertical shift
λγx	LGAX	1	1	Scale factor of camber for Fx
λCy	LCY	1	0.95	Scale factor of Fy shape factor
λμy	LMUY	1	0.6	Scale factor of Fy peak friction coefficient
λEy	LEY	1	1	Scale factor of Fy curvature factor
λKy	LKY	1	1.15	Scale factor of Fy cornering stiffness
λHy	LHY	0	1	Scale factor of Fy horizontal shift
λVy	LVY	0	1	Scale factor of Fy vertical shift
λγy	LGAY	1	0.6	Scale factor of camber for Fy
λt	LTR	1	1	Scale factor of Peak of pneumatic trail
λMr	LRES	0	0	Scale factor for offset of residual torque
λγz	LGAZ	1	1	Scale factor of camber for Mz
λMx	LMX	1	1	Scale factor of overturning couple
λvMx	LVMX	0	0	Scale factor of Mx vertical shift
λMy	LMY	1	1	Scale factor of rolling resistance torque
λxα	LXAL	1	1.3	Scale factor of alpha influence on *Fx*
λyκ	LYKA	1	1.3	Scale factor of alpha influence on *Fy*
λ*Vy*κ	LVYKA	1	1	Scale factor of kappa induced *Fy*
λs	LS	1	1	Scale factor of Moment arm of *Fx*

6. Inflation Pressure Guide

For good performance of the tire, the footprint should be large while the contact pressure distribution should be as homogeneous as possible. To achieve this, the right inflation pressure for the right application is crucial. In general, less inflation pressure gives a larger contact area, but increases tire deformation. Low inflation pressures can be of benefit for the longitudinal performance, i.e. in the acceleration event, but decrease the lateral performance of the car in terms of grip and handling.

The inflation pressure guide aims to provide a range of appropriate inflation pressures regarding the actual tire load (dynamically loaded tire) and application.

Explanations:

x-axis (Normal Load):	the dynamic tire load for the condition of interest (*static load + load transfer from longitudinal / lateral acceleration + aerodynamic load*)
y-axis (Inflation Pressure):	
lat. performance zone:	recommended range for cornering performance
long. performance zone:	recommended range for drive/brake performance

6. Inflation Pressure Guide