



DYNATIRE "ROAD & TRACK"

A STATISTICAL TIRE MODEL

FOR ROAD & TRACK APPLICATION

DYNATIRE "ROAD & TRACK" IS A GENERIC TIRE MODEL BASED ON A UNIQUE MULTI-DIMENSIONAL STATISTICAL FIT TO A POOL OF STATISTICALLY REPRESENTATIVE COMBINATIONS OF TIRE PROPERTIES & OPERATING POINTS ("DATA SETS"), ALLOWING TO PREDICT KEY FUNDAMENTAL TIRE CHARACTERISTICS FOR GIVEN VERTICAL LOADS, TIRE DIMENSIONS AND INFLATION PRESSURES.

SHOW PACE/JKA SECTION | **SHOW DYNATUNE-XL SECTION**

HIDE PACE/JKA SECTION | **HIDE DYNATUNE-XL SECTION**

SHOW DYNATUNE QUADRATIC FIT DATA

DYNATIRE "RT" INPUT DATA		Reference Load Fz [N]	Tire Width [mm]	Aspect Ratio [%]	Rim Diameter [Inch]	Inflation Pressure [kPa]
<input type="checkbox"/> SLICK/RACE	TIRE 1	4000	27	45	18	250
<input type="checkbox"/> SLICK/RACE	TIRE 2	4000	225	45	18	250

CALC / SHOW TIRE 1 DATA & GRAPHS | CALC / SHOW TIRE 2 DATA & GRAPHS

OPTIONAL CUSTOM SCALING FACTORS*		
ONLY "CUSTOM" TIRES	TIRE 1	TIRE 2
Grip Coefficient μ	1.00	1.00
Cornering Stiffness	1.00	1.00
Aligning Torque Stiffness	1.00	1.00

* All Scaling Factors should be set to 1 for Road Tire Data Fits

DYNATIRE "RT" GRAPHICAL RESULTS

$\mu = f(Fz)$

$CS = f(Fz)$

$ATS = f(Fz)$

$Kz = f(Fz)$

$DLR = f(Fz)$

DYNATIRE "RT" QUADRATIC DATA FITS $y(x) = a * x^2 + b * x + c$ with $x = Fz [N]$															
LOAD RANGE FIT 1000 N - 8000 N	Grip Factor $\mu = f(Fz)$			Cornering Stiffness $CS = f(Fz)$			Align. Torque Stiff. $ATS = f(Fz)$			Vertical Stiffness $Kz = f(Fz)$			Dyn. Loaded Radius $= f(Fz)$		
	a	b	c	a	b	c	a	b	c	a	b	c	a	b	c
TIRE 1	9.291E-24	-4.466E-05	1.374E+00	-1.152E-05	4.001E-01	-1.492E+01	9.317E-07	3.828E-03	2.937E+00	-3.325E-08	1.323E-02	2.325E+02	7.720E-08	-4.149E-03	3.298E+02
TIRE 2	9.291E-24	-4.466E-05	1.374E+00	-1.152E-05	4.001E-01	-1.492E+01	9.317E-07	3.828E-03	2.937E+00	-3.325E-08	1.323E-02	2.325E+02	7.720E-08	-4.149E-03	3.298E+02

The DYNATIRE "RT" Statistical Tire Model is based on a Multi-Dimensional Data Fit on a statistically representative quantity of specific Operating Points ("DATA SETS") of STREET-LEGAL and SLICK / RACE Tires. For User Convenience, Input Data Sets can be entered for 2 Different Tires allowing an easy comparison.

DYNATIRE "RT" Input Data Sets are consisting out of:

- Vertical Load Fz
- Tire Dimensions - Width / Aspect Ratio / Rim Size
- Inflation Pressure
- Road of Track Application Switch

DYNATIRE "RT" INPUT DATA		Reference Load Fz [N]	Tire Width [mm]	Aspect Ratio [%]	Rim Diameter [Inch]	Inflation Pressure [kPa]
<input checked="" type="checkbox"/> SLICK/RACE	TIRE 1	5000	275	30	21	250
<input type="checkbox"/> SLICK/RACE	TIRE 2	5000	275	30	21	250





"DYNATIRE RT DATA SET"	OPERATING RANGE "ROAD"	OPERATING RANGE "TRACK"
- Vertical Load Fz in [N]	1000 - 10000	1000 - 7500
- Tire Width in [mm]	155 - 355	190 - 335
- Aspect Ratio in [%]	25 - 75	30 - 65
- Rim Diameter in [inch]	13 - 23	10 - 20
- Inflation Pressure in [kPa]	180 - 325	85 - 260

The picture to the left does show the Input Parameters and their valid "Operating" Ranges - for which the Prediction Model in **DYNATIRE "RT"** has been calibrated - both for Road as for Track (Racing) Tires.

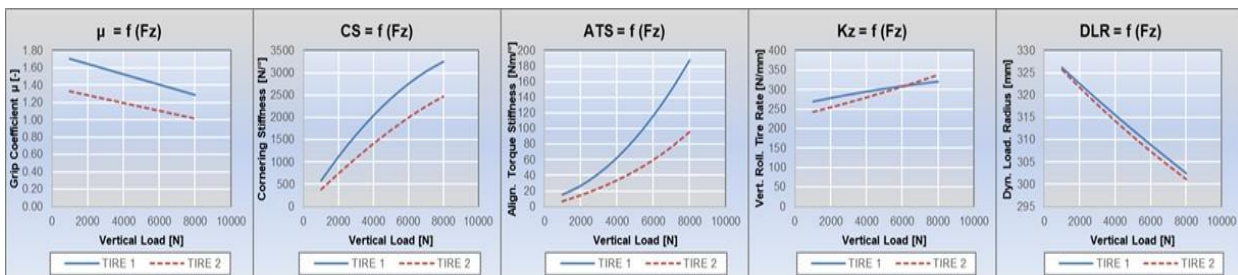
PRIMARY RESULTS

The **DYNATIRE "RT"** Model provides instantly - for a given Selection of Specific Input Data Sets - Numerical and Graphical Results for the following Key Tire Characteristics:

- Tire Lateral Grip Coefficient μ
- Tire Cornering Stiffness **CS**
- Tire Aligning Torque Stiffness **ATS**
- Tire Vertical Stiffness (Rolling Tire) **Kz**
- Tire Dynamic Rolling Radius **DLR**
- Tire Vertical Load Sensitivity for μ , **CS**, **ATS**, **Kz** & **DLR** as function of Vertical Load **Fz**

PRIMARY GRAPHICAL RESULTS

The above mentioned Tire Characteristics are presented graphically in 5 separate charts, all as a Function of Vertical Load Fz Variance, allowing an instant Panoramic Overview of all Key Performance Characteristics:



PRIMARY NUMERICAL RESULTS

Specific Numerical Results for selected Input Data Sets are presented in 2 Different Data Formats:

The first Data Format provides the above-mentioned Tire Characteristics in the **DYNATUNE-XL ENHANCED TIRE MODEL** Data Format, allowing as such a straightforward direct implementation into the **DYNATUNE-XL RIDE & HANDLING MODULE**.

DYNATUNE-XL ENHANCED TIRE INPUT DATA SET			
	TIRE 1		TIRE 2
Reference Load	5000	[N]	5000
Grip μ	1.55	[-]	1.31
Cornering Stiffness	2598.36	[N/m]	2151.41
Aligning Torque Stiffness	111.82	[Nm/m²]	55.62
Load Dep. CS & ATS	46.02	[%]	62.94
Load Dependency μ	3.09	[%/kN]	3.89

The second available data format presents the tire characteristics using a **Reduced-Order 4-Term PACEJKA TIRE MODEL**, based on the widely recognized B, C, D₁, and D₂ Coefficients.

These parameters define the fundamental **PACEJKA MAGIC FORMULA** used to model Lateral Force and Aligning Moment, as illustrated in the **MAGIC FORMULA** to on the next page.





PACEJKA REDUCED ORDER 4 TERM TIRE MODEL (BCD₂)

$$F_y = - ((F_{y_D1} + F_{y_D2} * F_z/1000) * F_z) * \sin(F_{y_C1} * \text{ATAN}((F_{y_B1}) * \alpha))$$

$$M_z = - ((M_{z_D1} + M_{z_D2} * F_z/1000) * F_z) * \sin(M_{z_C1} * \text{ATAN}((M_{z_B1}) * \alpha))$$

The **PACEJKA MAGIC FORMULA** does represent the Key Tire Performance Characteristics with specifically fitted Coefficients. Due some inherent differences in this data representation numeric values for Cornering Stiffness and Aligning Torque Stiffness can differ slightly from the **DYNATUNE-XL ENHANCED TIRE MODEL** Values.

DYNATUNE-XL ENHANCED TIRE MODEL FIT		ETRTO Radius [mm]	Dyn. Load. Radius [mm]	Roll. Vert. Stiff. Kz [N/mm]	Cornering Stiffness [N ²]	AT Stiffness [Nm ²]	Grip μ [-]
RESULTS FOR REF. LOAD [N]	5000 TIRE 1	349.20	331.71	285.41	2598.36	111.82	1.55
	5000 TIRE 2	349.20	331.01	288.77	2151.41	55.62	1.31

PACEJKA COEFFICIENTS (BCD ₂)		D1	D2	B1	C1
Reduced Order 4 Term Fy Coefficients	TIRE 1	1.709E+00	-3.089E-02	3.056E-01	1.138E+00
Reduced Order 4 Term Mz Coefficients	TIRE 1	1.406E-02	4.447E-03	2.121E-01	3.026E+00
Reduced Order 4 Term Fy Coefficients	TIRE 2	1.503E+00	-3.889E-02	2.288E-01	1.419E+00
Reduced Order 4 Term Mz Coefficients	TIRE 2	8.662E-03	1.769E-03	2.212E-01	2.974E+00

Special Feature: The Graphical Representation of the Statistical Results are available as Quadratic Curve Fits allowing a quick implementation in for instance Bicycle Models etc in other Software Tools.

DYNATIRE "RT" QUADRATIC DATA FITS		$y(x) = a * x^2 + b * x + c$ with $x = F_z$ [N]													
LOAD RANGE FIT 1000 N - 8000 N	Grip Factor $\mu = f(F_z)$			Cornering Stiffness CS = f(Fz)			Align. Torque Stiff. ATS = f(Fz)			Vertical Stiffness Kz = f(Fz)			Dyn. Loaded Radius = f(Fz)		
	a	b	c	a	b	c	a	b	c	a	b	c	a	b	c
TIRE 1	1.858E-24	-3.089E-05	1.709E+00	-3.507E-05	6.950E-01	-5.684E-13	3.696E-06	2.170E-03	8.560E+00	-2.810E-06	1.902E-02	2.606E+02	-4.290E-08	-3.193E-03	3.487E+02
TIRE 2	1.115E-23	-3.889E-05	1.503E+00	-2.175E-05	5.718E-01	-1.800E+02	1.520E-06	2.812E-03	3.914E+00	-3.097E-06	2.674E-02	2.325E+02	-7.793E-09	-3.505E-03	3.487E+02

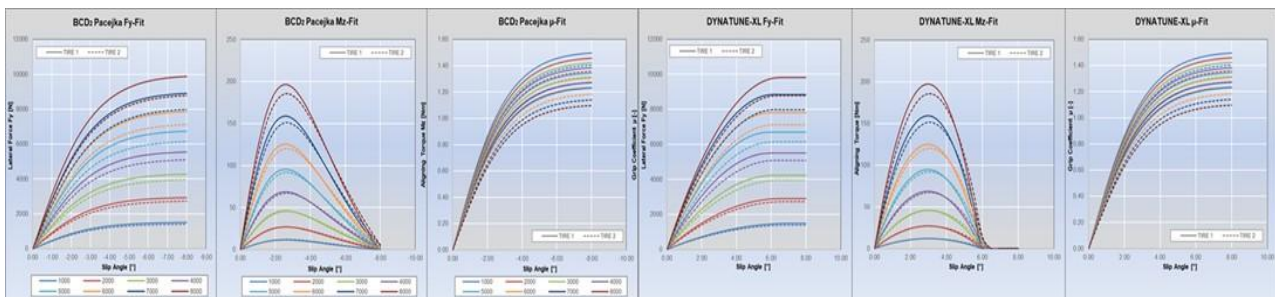
SECONDARY RESULTS

The **Primary Results** presented above from the **DYNATIRE "RT" STATISTICAL TIRE MODEL** effectively reflect the core **Statistical Outputs**.

By integrating a Unique Tire Model Map Generation Algorithm – more info can be found on the DYNATUNE-XL website - into **DYNATIRE "RT"**, the Module can also produce accurate predictions of look-up tables for **Lateral Force** and **Aligning Moment** as a function of **Slip-Angle** and **Vertical Load**. These Tire Maps are available in both the **DYNATUNE-XL ENHANCED TIRE MODEL** Format and the **BCD₂ PACEJKA TIRE Model** format.

SECONDARY GRAPHICAL RESULTS

The image below shows the **Graphical Representation of the Tire Look-Up Table Maps** generated by each tire modeling approach. While the **Lateral Force F_y** and the corresponding **Grip Coefficient μ** are nearly identical across models, more noticeable differences appear in the shape of the **Aligning Moment**. These variations are primarily caused by the more refined approximation of Aligning Torque behavior achieved through the **PACEJKA Curve Fitting Procedure**, which is directly influenced by the **Curvature "C" Factor Value**.





SECONDARY NUMERICAL RESULTS

The Tire Table Maps are also available to the User in Numerical Format for the above shown Tire Characteristics. For convenient navigation on the Worksheet these tables can be hidden if not needed.

SHOW ALL TABLES SHOW Fy TABLE SHOW Mz TABLE SHOW μ TABLE									HIDE ALL TABLES HIDE Fy TABLE HIDE Mz TABLE HIDE μ TABLE									
TIRE 1	PACEJKA Fy = f(α, Fz) 275/30/21 - 250kPa								TIRE 2	PACEJKA Fy = f(α, Fz) 275/30/21 - 250kPa								
	Fz									Fz								
α	1000.0	2000.0	3000.0	4000.0	5000.0	6000.0	7000.0	8000.0	α	1000.0	2000.0	3000.0	4000.0	5000.0	6000.0	7000.0	8000.0	
0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
-0.50	295.1	579.6	853.5	1116.8	1369.5	1611.6	1843.1	2064.0	-0.50	236.4	460.3	671.7	870.5	1056.8	1230.7	1391.9	1540.7	
-1.00	569.2	1117.9	1646.2	2154.0	2641.4	3108.3	3554.7	3980.7	-1.00	460.9	897.5	1309.6	1697.3	2060.6	2399.6	2714.0	3004.1	
-1.50	807.6	1586.2	2335.8	3056.3	3747.9	4410.4	5043.8	5648.3	-1.50	664.1	1293.1	1886.9	2445.6	2969.0	3457.3	3910.5	4328.5	
-2.00	1004.8	1973.4	2905.9	3802.4	4662.7	5486.9	6275.0	7027.0	-2.00	840.3	1636.1	2387.4	3094.2	3756.5	4374.4	4947.7	5476.5	
-2.50	1162.1	2282.4	3361.0	4397.8	5392.9	6346.1	7257.7	8127.4	-2.50	987.6	1922.8	2805.8	3636.5	4414.9	5141.0	5814.8	6436.3	
-3.00	1285.0	2523.8	3716.5	4862.9	5963.2	7017.3	8025.3	8987.0	-3.00	1107.1	2155.5	3145.4	4076.6	4949.2	5763.1	6518.5	7215.2	
-3.50	1380.0	2710.4	3991.2	5222.4	6404.0	7536.0	8618.4	9651.3	-3.50	1201.8	2340.0	3414.5	4425.4	5372.6	6256.3	7076.2	7832.6	
-4.00	1453.1	2854.0	4202.7	5499.2	6743.4	7935.4	9075.2	10162.8	-4.00	1275.4	2483.4	3623.7	4696.6	5701.9	6639.6	7509.8	8312.5	
-4.50	1509.5	2964.8	4365.8	5712.6	7005.1	8243.4	9427.5	10557.2	-4.50	1331.8	2593.0	3783.7	4903.9	5953.6	6932.8	7841.5	8679.6	
-5.00	1553.2	3050.6	4492.1	5877.9	7207.8	8481.9	9700.2	10862.7	-5.00	1374.2	2675.6	3904.3	5060.2	6143.3	7153.7	8091.2	8956.1	
-5.50	1587.2	3117.4	4590.5	6006.6	7365.6	8667.6	9912.6	11100.5	-5.50	1405.6	2736.8	3993.6	5176.0	6283.9	7317.4	8276.4	9161.0	
-6.00	1613.9	3169.7	4667.6	6107.4	7489.3	8813.2	10079.0	11289.6	-6.00	1428.5	2781.4	4058.6	5260.2	6386.1	7436.4	8411.1	9310.1	
-6.50	1634.9	3211.0	4728.4	6187.0	7586.9	8928.0	10210.3	11433.9	-6.50	1444.7	2812.9	4104.7	5319.9	6458.6	7520.8	8506.6	9415.8	
-7.00	1651.6	3243.8	4776.6	6250.1	7664.3	9019.1	10314.5	11550.6	-7.00	1455.8	2834.5	4136.1	5360.7	6508.1	7578.5	8571.8	9488.0	
-7.50	1664.9	3269.9	4815.1	6300.5	7726.1	9091.8	10397.7	11643.7	-7.50	1462.9	2848.4	4156.4	5386.9	6540.0	7615.5	8613.7	9534.4	
-8.00	1675.6	3290.9	4846.0	6340.9	7775.6	9150.1	10464.4	11718.4	-8.00	1467.0	2856.3	4168.0	5401.9	6558.2	7636.8	8637.7	9560.9	
-8.00	1675.6	3290.9	4846.0	6340.9	7775.6	9150.1	10464.4	11718.4	-8.00	1467.0	2856.3	4168.0	5401.9	6558.2	7636.8	8637.7	9560.9	
-8.00	1675.6	3290.9	4846.0	6340.9	7775.6	9150.1	10464.4	11718.4	-8.00	1467.0	2856.3	4168.0	5401.9	6558.2	7636.8	8637.7	9560.9	
-8.00	1675.6	3290.9	4846.0	6340.9	7775.6	9150.1	10464.4	11718.4	-8.00	1467.0	2856.3	4168.0	5401.9	6558.2	7636.8	8637.7	9560.9	
-8.00	1675.6	3290.9	4846.0	6340.9	7775.6	9150.1	10464.4	11718.4	-8.00	1467.0	2856.3	4168.0	5401.9	6558.2	7636.8	8637.7	9560.9	
-8.00	1675.6	3290.9	4846.0	6340.9	7775.6	9150.1	10464.4	11718.4	-8.00	1467.0	2856.3	4168.0	5401.9	6558.2	7636.8	8637.7	9560.9	
-8.00	1675.6	3290.9	4846.0	6340.9	7775.6	9150.1	10464.4	11718.4	-8.00	1467.0	2856.3	4168.0	5401.9	6558.2	7636.8	8637.7	9560.9	

ADDITIONAL FEATURES

PACEJKA MF 52 MAGIC FORMULA TIRE PERFORMANCE ANALYSIS TOOL

For Maximum User convenience, DYNATUNE-XL has integrated a dedicated PACEJKA MF 5.2 TIRE DATA PLOTTER and PERFORMANCE ANALYSIS TOOL directly into the DYNATIRE "RT" Module. Users can import original MF 5.1 / MF 5.2 *.TIR files for detailed visualization and analysis.

DEMO TIRE

Scaling Factors	Fx Coefficients	Fy Coefficients	Mx Coefficients	My Coefficients	Mz Coefficients
LFZ0	PCX1	PCY1	QSX1	QSY1	QBZ1
LCX	PDX1	PDY1	QSX2	QSY2	QBZ2
LMUX	PDX2	PDY2	QSX3	QSY2	QBZ3
LEX	PEX1	PDY3			QBZ4
LKX	PEX2	PEY1			QBZ5
LHX	PEX3	PEY2			QBZ9
LVX	PEX4	PEY3			QBZ10
LCY	PKX1	PEY4			QCZ1
LMUY	PKX2	PKY1			QDZ1
LEY	PKX3	PKY2			QDZ2
LKY	PHX1	PKY3			QDZ3
LHY	PHX2	PHY1			QDZ4
LVY	PVX1	PHY2			QDZ6
LGAY	PVX2	PHY3			QDZ7
LTR	RBX1	PVY1			QDZ8
LRES	RBX2	PVY2			QDZ9
LGAX	RCX1	PVY3			QEZ1
LXAL	RHX1	PVY4			QEZ2
LYKA	PTX1	RBY1			QEZ3
LVIKA	PTX2	RBY2			QEZ4
LS	PTX3	RBY3			QEZ5
LSGKP		RCY1			QHZ1
LSGAL		RHY1			QHZ2
LGYR		RVY1			QHZ3
LMX		RVY2			QHZ4
LMY		RVY3			SSZ1
		RVY4			SSZ2
		RVY5			SSZ3
		RVY6			SSZ4
		PTY1			QTZ1
		PTY2			MBELT

Test Conditions

Fz Min: 0.00 N

Fz Max: 20000.00 N

α Min: -55.00 °

α Max: 55.00 °

γ Min: -10.31 °

γ Max: 10.31 °

κ Min: -150.00 %

κ Max: 150.00 %

Test Conditions

Vertical Stiffness Kz: 378.66 N/mm

Inflation Pressure: 0.00 kPa

**LOAD MF 5.2
TIRE DATA
*.TIR FILE**

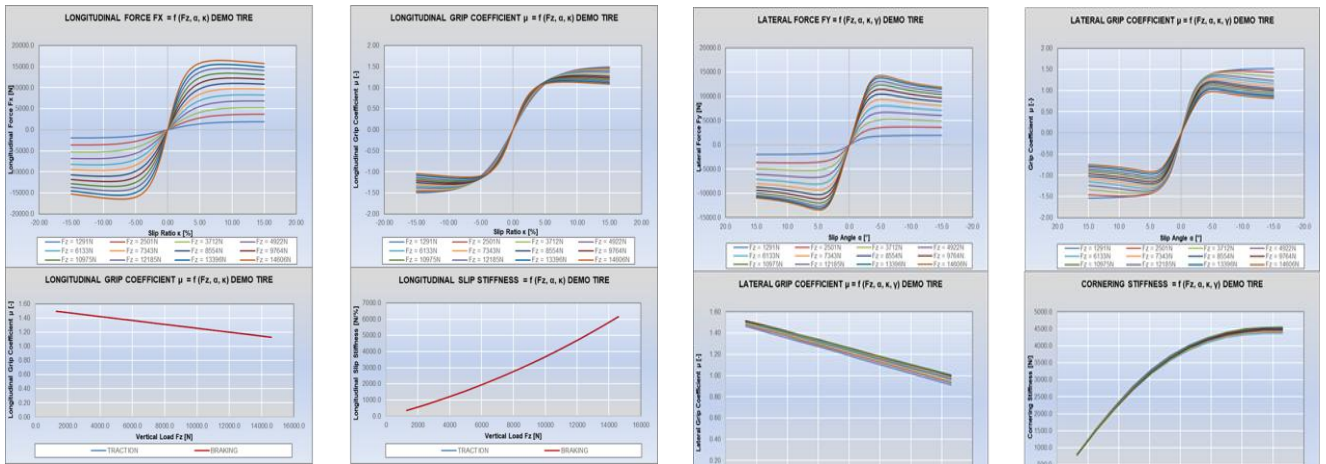
ISO sign conventions.

Click on Picture for MF52 Pacejka Model Manual

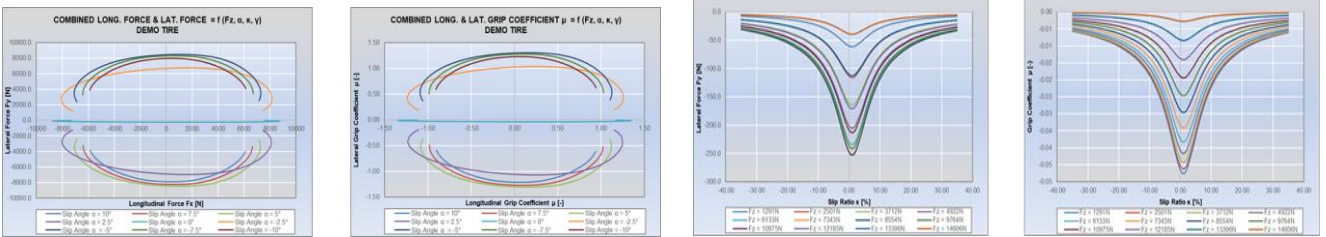




Below a selection of the available Data Graphs for F_x , F_y , M_x , M_z and Combined Slip Conditions:

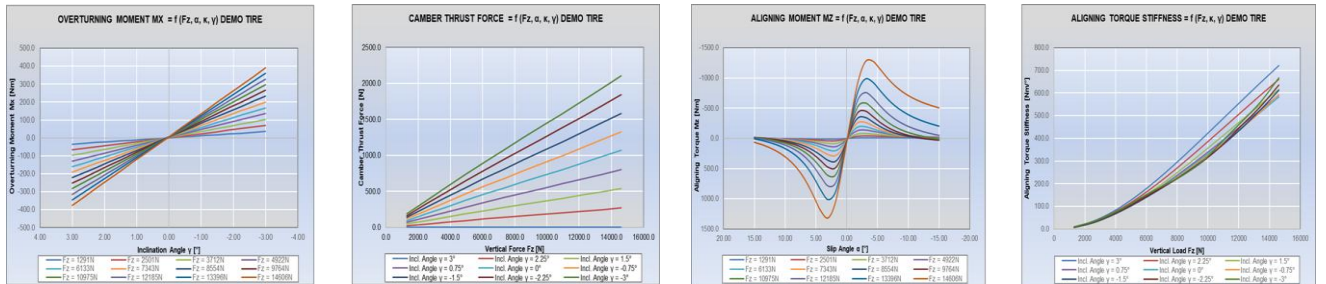


LONGITUDINAL FORCE F_x



COMBINED SLIP F_x & F_y

LATERAL FORCE F_y



OVERTURNING MOMENT M_x

ALIGNING MOMENT M_z

DYNATIRE "RT" MODELING

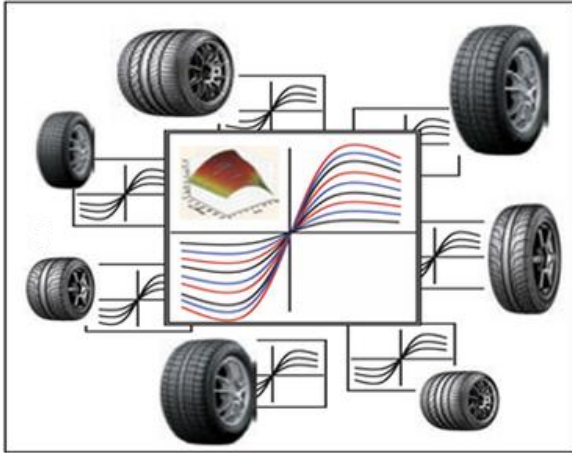
DYNATIRE "RT" is a Generic Tire Model developed through the fitting of a statistically sufficiently large volume of Specific Tire Operating Points, using a multi-dimensional, non-linear fitting method originally pioneered by Honda Motor Company. The core concept is illustrated in the images below, which demonstrates how "Data Sets" from various Tire Properties and their Operating Points are merged into a Single, Comprehensive Multi-Dimensional Model.

DYNATUNE-XL has further refined this methodology, developing its own proprietary algorithm to enhance fit accuracy and model generalization:

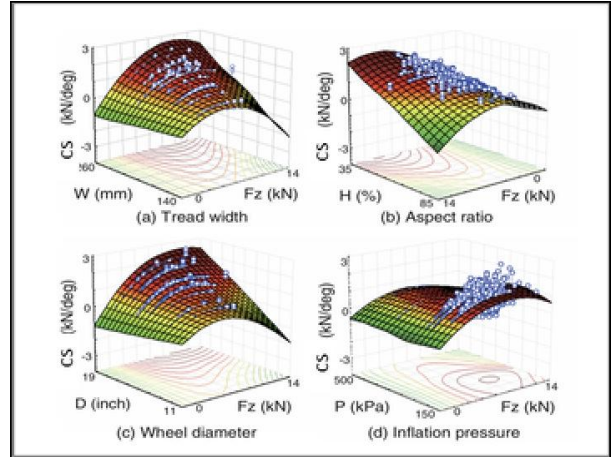




Classic Tire Data Fitting Approach

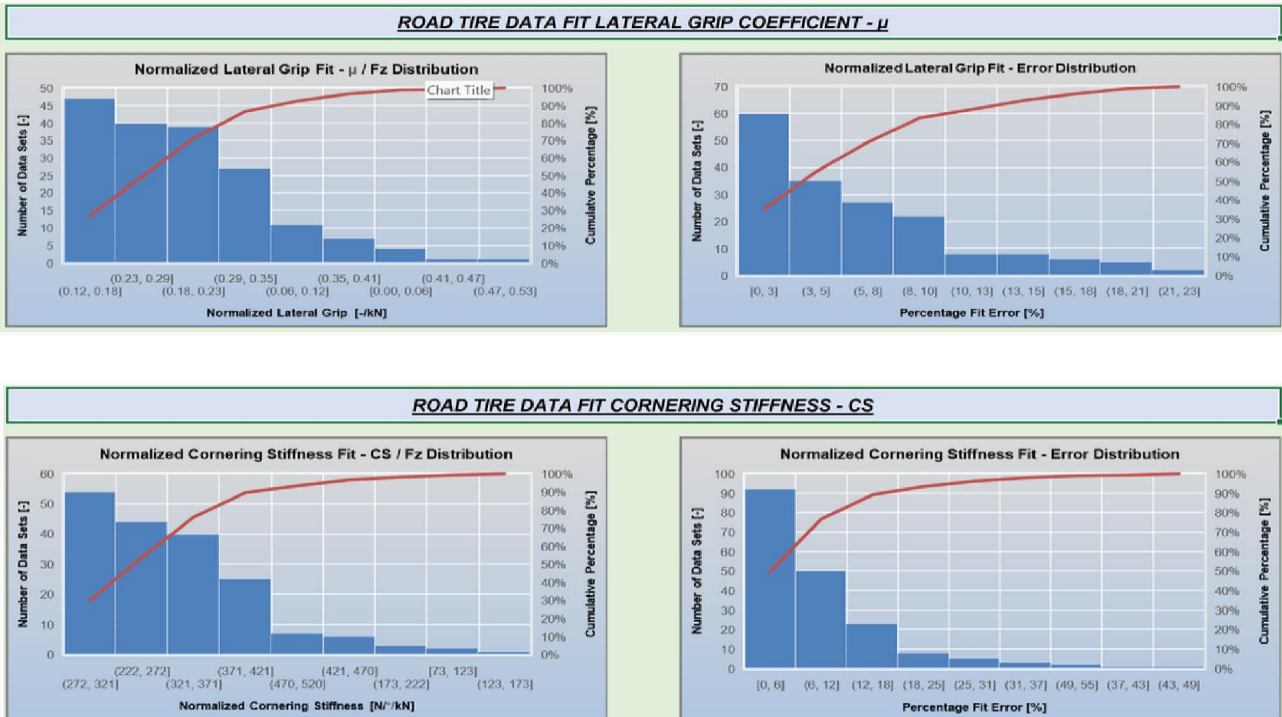


Multi-Dimensional "Operating Point" Fitting Approach



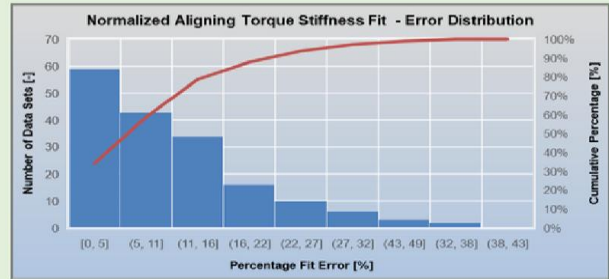
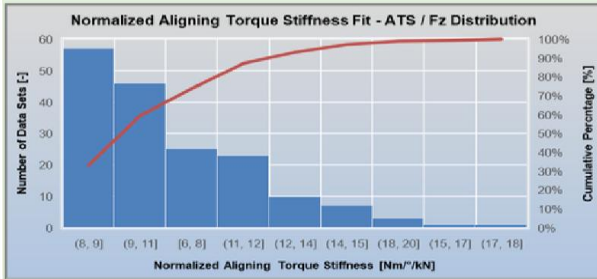
STATISTICAL RELEVANCE

In the histograms below, all characteristics have been **normalized with respect to vertical load (Fz)**. The statistical distributions shown have been generated based on the **DYNATIRE "RT" fit**, and are compared - across all available Tire Properties - for specific combinations of **Vertical Load, Tire Dimensions, and Inflation Pressure**, against the **Original Reference Tire Operating Points**.

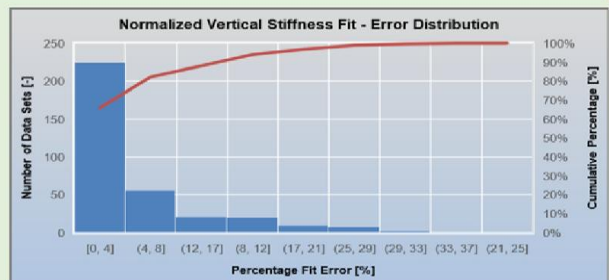
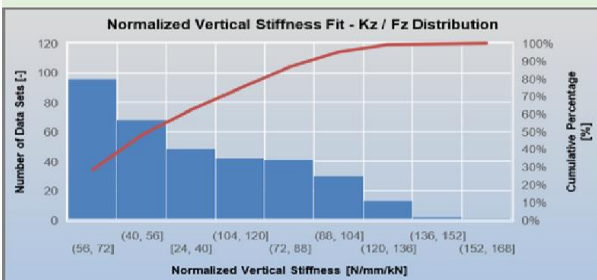




ROAD TIRE DATA FIT ALIGNING TORQUE STIFFNESS - ATS

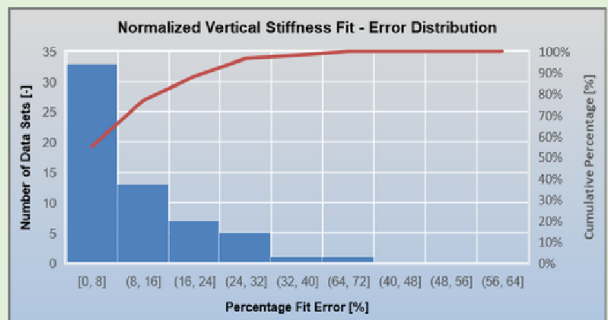
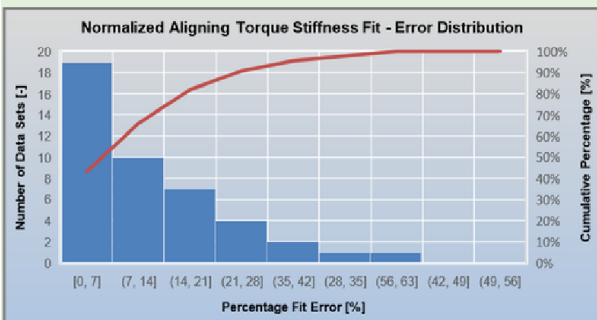
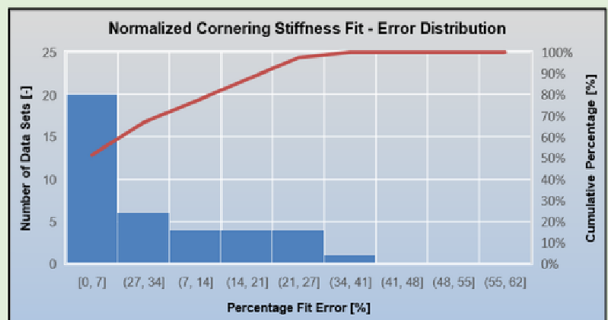
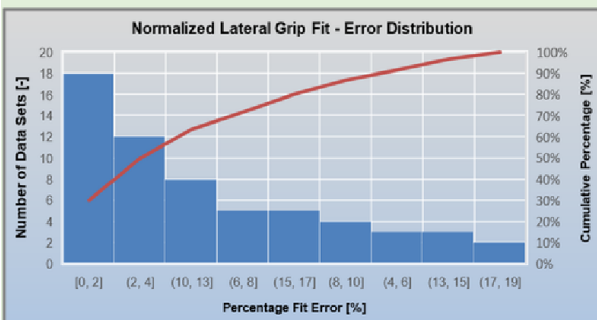


ROAD TIRE DATA FIT VERTICAL STIFFNESS - Kz



The error distributions for **Track Tires** are shown below. While the correlation is, generally speaking, slightly lower - due to the increased complexity of slick tire behavior - the Results produced by the **DYNATIRE "RT" Slick Tire Prediction Model** remain adequate and fit for purpose.

RACE/TRACK TIRE DATA FITS - STATISTICAL ERROR DISTRIBUTION





SOFTWARE REQUIREMENTS & LICENSE MANAGEMENT

Software requirements for **DYNATUNE RELEASE 1.0** and **DYNATUNE-XL RELEASE 8.0** onward are **Full** Versions (incl. latest updates) of **MS EXCEL® 2010, 2013, 2016, 2019, 2021 & 2024** or **Office/365** with a **MS Windows® XP, Windows Vista, Windows 7 Starter, Windows 7, Windows 8, Windows 10** or **11** Operating System.

All Modules of **DYNATUNE-XL** Software Suite come as a compiled executable (*.exe) binary file which will call **MS EXCEL®** as a separate stand-alone instance. Source code is copyright protected and safe data handling is guaranteed through secure binary files.

The Software Lease Program offers Standard **B2C** Licenses which are typically valid for the use of the workbooks (and ALL user-saved variants) on 1 computer, for 1 user only and are typically valid for 1 year. Special offers can be made available to **B2B** Customers on request.

The Copyright Protection Software does offer to the customer next to the security of encoded binary data handling also - by means of a unique License Key Verification Procedure - a state-of-the-art data protection - ensuring that no one else can have an unauthorized access to your valuable software modules or data.

License support is available for the latest releases only. Updates and Bugfixes are available to the subscribers of the Software Lease Program.

Recommended minimum hardware configuration for the **DYNATUNE-XL** Tool-Set is a computer with Intel Core i7 CPU (or similar) with a minimum of 8GB Ram.

All Units in **DYNATUNE-XL** are **SI**.

DYNATUNE-XL DEMO VERSIONS

DEMO Versions of the following **DYNATUNE-XL** Modules can be downloaded here:

- DYNATUNE Ride & Handling Module: <http://www.dynatune-xl.com/download-demo-rh.html>
- DYNATUNE Suspension Design Module: <http://www.dynatune-xl.com/download-demo-sdm.html>
- DYNATUNE Suspension Tuning Module: <http://www.dynatune-xl.com/download-demo-stm.html>

DYNATUNE-XL STORE

B2C customers can acquire the various **DYNATUNE-XL** Modules online in our webstore:

http://www.dynatune-xl.com/store/c1/Featured_Products.html

B2B customers are kindly requested to contact us directly.

DYNATUNE-XL CONTACT

Website: www.dynatune-xl.com

Email: info@dynatune-xl.com

