Università degli Studi di Padova – Dipartimento di Ingegneria Industriale

Corso di Laurea in Ingegneria Aerospaziale

Relazione per la prova finale «Parameter identification of the MF-Tyre model: application to FSAE tyres»

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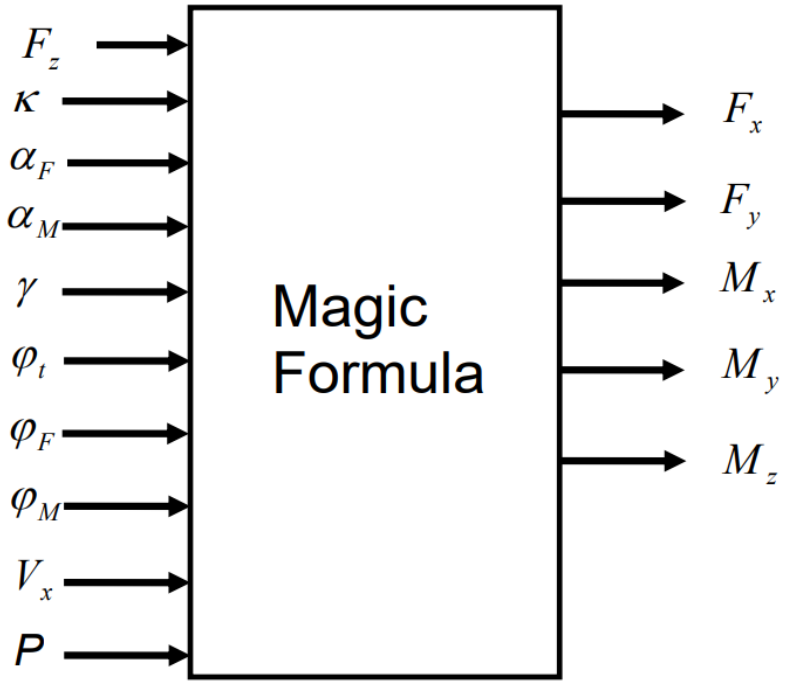
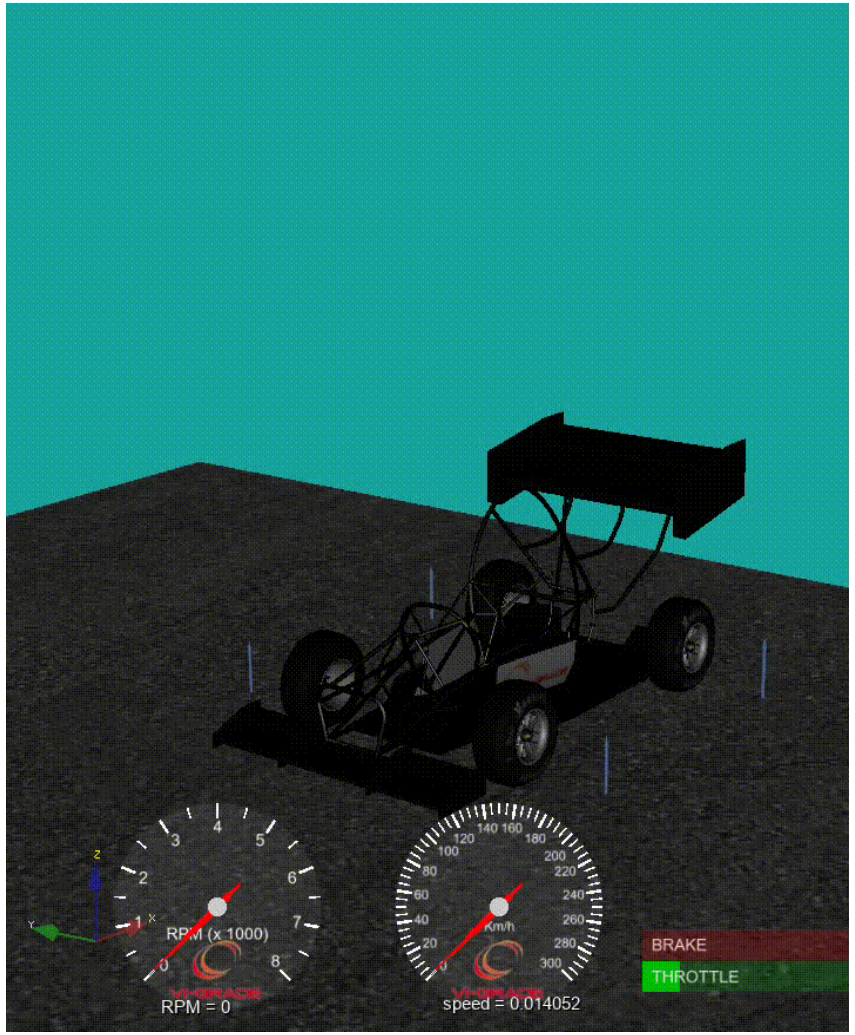
INTRODUCTION

The tyre is a **system** that gives 5 main outputs.

With Pacejka's Magic Formula it is possible to model this system using MF-Tool product.



THESIS OBJECTIVES



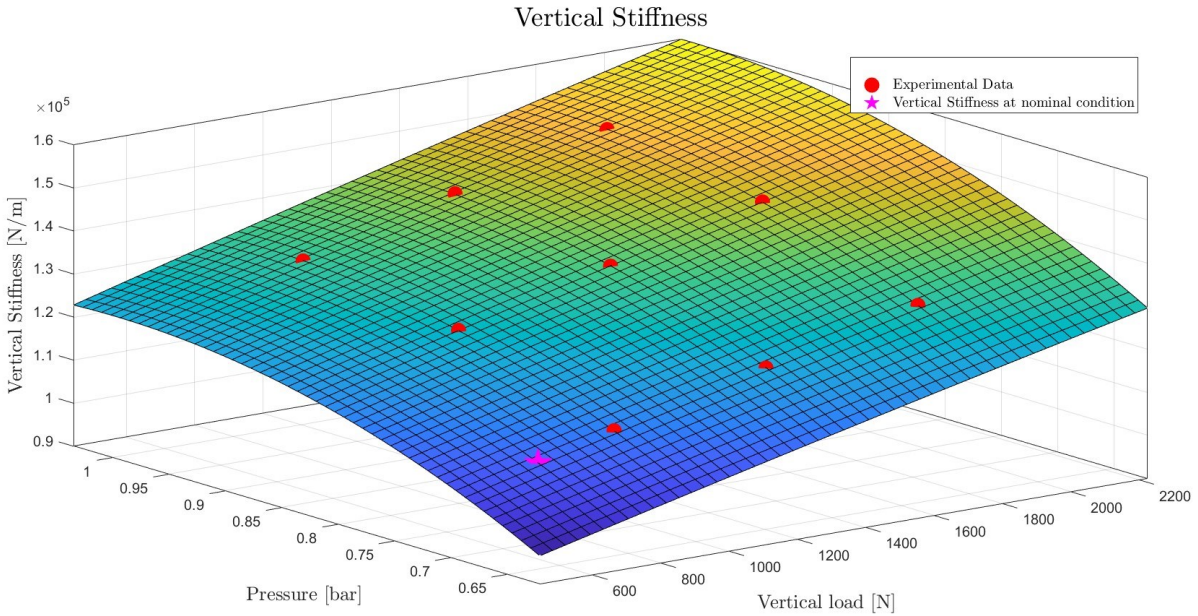
How can a software understand the physics of a tyre and **simulate** its dynamic response?

Magic Formula describes the tyre behaviour with coefficients contained in a **tyre property file**.
The **objective** of this thesis is to **create** one property file to run multi-body simulations.

TYRE: CHOICE

Hoosier 16x7.5-10 LC0 was chosen to reduce **weight** and **inertia** of the un-sprung masses with enough tread to unload the torque of the motors.

The **nominal condition** of our tyre is **667 N and 0.69 bar**, with a vertical stiffness of **109739.7 N/m**.



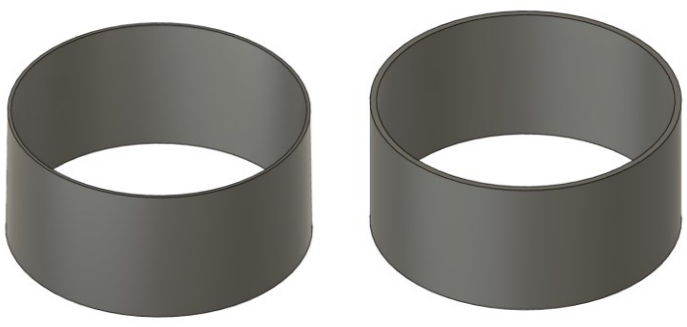
Size	O.D.	Tread Width	Compound	Approx. Weight
16.0 x 6.0-10	16.3"	6.0"	R20, LCO	7 lbs.
16.0 x 7.5-10	16.2"	7.3"	R20, LCO	8 lbs.
6.0/18.0-10	18.0"	6.0"	LC0	8 lbs
18.0 x 6.0-10	18.1"	6.2"	R20	9 lbs.
18.0 x 7.5-10	18.3"	7.5"	R20	10 lbs
20.5 x 7.0-13	21.0"	7.0"	R20	11 lbs.
20.0 x 7.5-13	20.6"	8.0"	R20	12 lbs.

TIRE SIZE: 16.0 x 7.5 - 10 | (43075)
COMPOUND = LC0 R25B
RIM WIDTH = 8"
PRELOAD = 0

	ACTUAL LOAD	STATIC SPRING RATE (lbs/in)
AIR = 10 PSI	200 lbs.	652 lbs.
	300 lbs.	700 lbs.
	400 lbs.	748 lbs.
AIR = 12 PSI	200 lbs.	724 lbs.
	300 lbs.	774 lbs.
	400 lbs.	824 lbs.
AIR = 14 PSI	200 lbs.	755 lbs.
	300 lbs.	809 lbs.
	400 lbs.	859 lbs.

TYRE GEOMETRY

	Old tyre	New tyre
Total mass	2.9 *kg*	3.5 *kg*
Shoulders mass	1.55 *kg*	1.55 *kg*
Tread mass	1.35 *kg*	1.95 *kg*
Shoulder thickness	10.2 *mm*	10.2 *mm*
Tread thickness	7.1 *mm* / 4.6 *mm*	8.5 *mm*
Steer moment of inertia	0.0824 kgm^2	
Rolling moment of inertia	0.1218 kgm^2	



DATA ACQUISITION

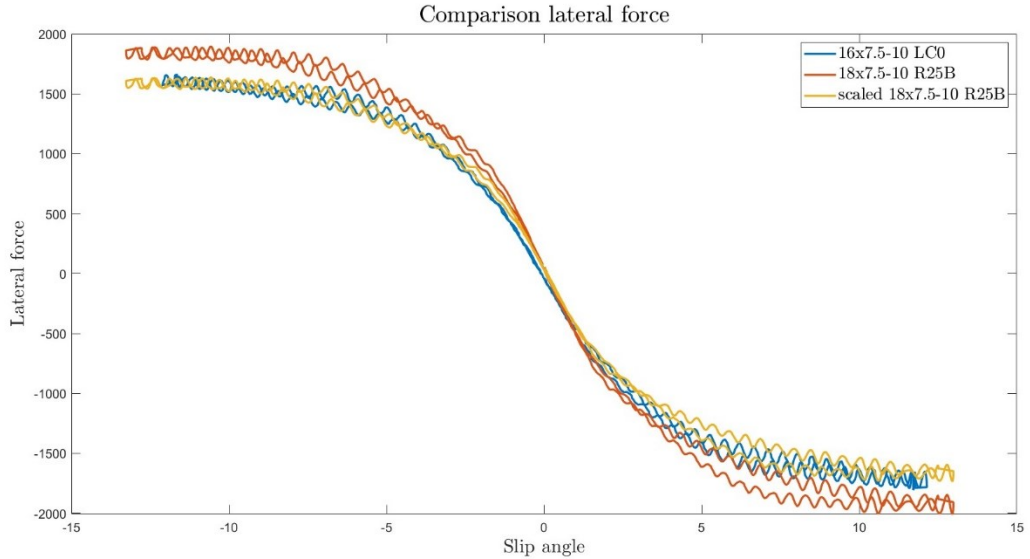
FSAE Tire Test Consortium worked with **Calspan** to test and measure the tyres that universities mostly use.
The Hoosier 16x7.5-10 LC0 was tested during **Round 8** in 2018 in lateral performance.

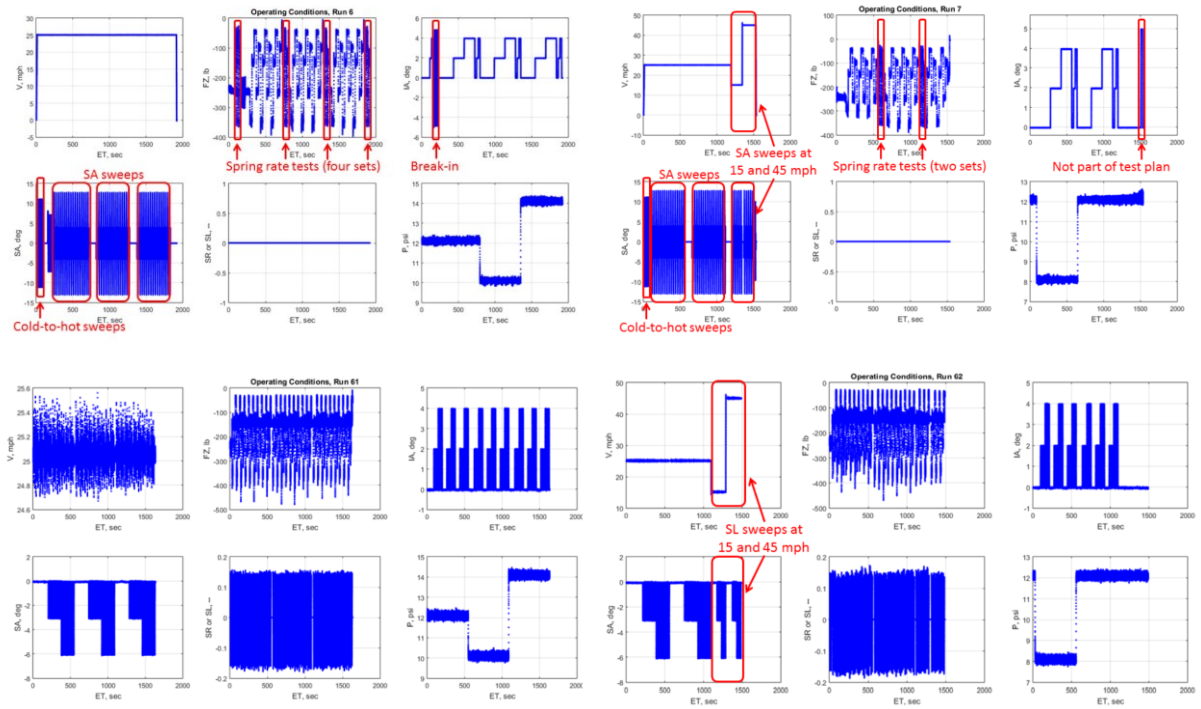
Channel	Units	Description
AMBTMP	degC or degF	Ambient room temperature
ET	sec	Elapsed time for the test
FX	N or lb	Longitudinal Force
FY	N or lb	Lateral Force
FZ	N or lb	Normal Load
IA	deg	Inclination Angle
MX	N-m or lb-ft	Overturning Moment
MZ	N-m or lb-ft	Aligning Torque
N	rpm	Wheel rotational speed
NFX	unitless	Normalized longitudinal force (FX/FZ)
NFY	unitless	Normalized lateral force (FY/FZ)
P	kPa or psi	Tire pressure
RE	cm or in	Effective Radius
RL	cm or in	Loaded Radius
RST	degC or degF	Road surface temperature
SA	deg	Slip Angle
SL	unitless	Slip Ratio based on RE (such that SL=0 gives FX=0)
SR	unitless	Slip Ratio based on RL (used for Calspan machine control, SR=0 does not give FX=0)
TSTC	degC or degF	Tire Surface Temperature--Center
TSTI	degC or degF	Tire Surface Temperature--Inboard
TSTO	degC or degF	Tire Surface Temperature--Outboard
V	kph or mph	Road Speed

TEST DATA

Lateral and longitudinal test are done with a sweep of slip angle and longitudinal slip at different:

- Vertical load
- Pressure
- Camber angle
- Speed





To have a complete description of the tyre it is possible to use the **data** taken for **Hoosier 18x7.5-10** and **scale** them.

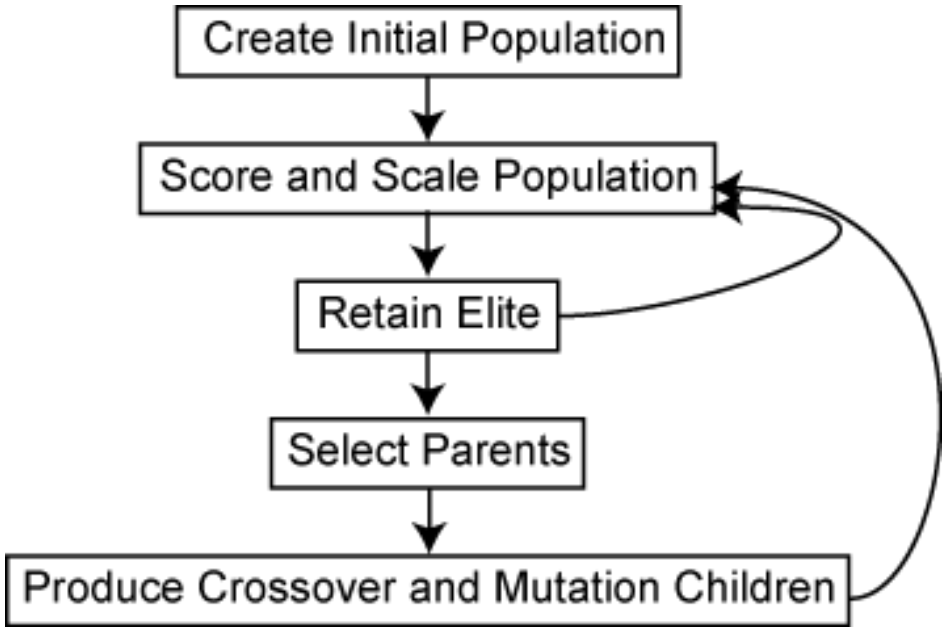
TYDEX CREATION

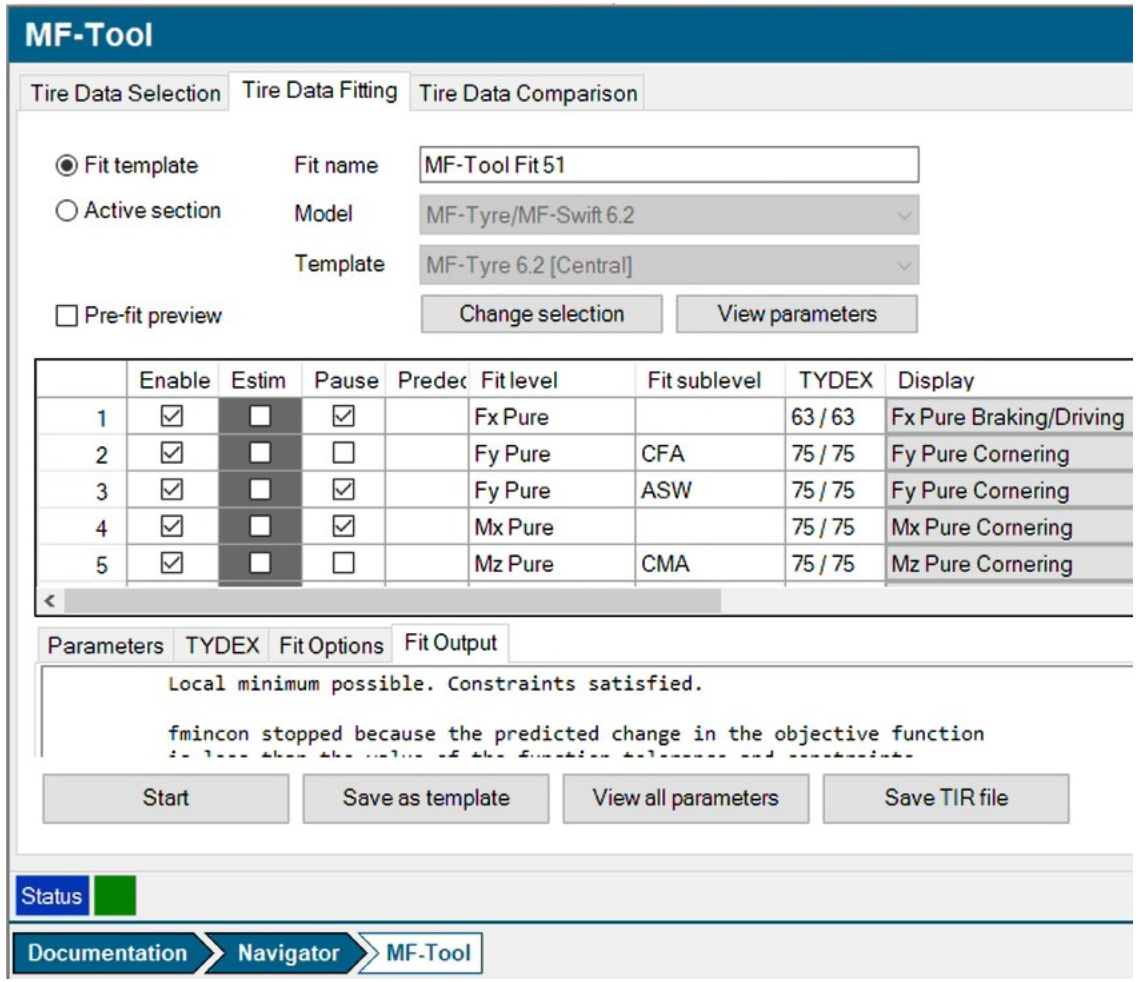
To perform the simulation the data must be **organised** into the file **TYDEX.**
Every TYDEX describes **one dynamic situation** of the tyre and has all the **data** that are **useful** to perform the simulation.

```
disp('Choose your 16" Cornering_2 Data')
pause(2)
[filename, pathname] = uigetfile('*.mat','','' );
t = importdata([pathname filename]);

names = t.channel.name;
nchans = size(t.channel.name,2);

for n = 1:nchans
    nchs = (join(string([names(n) '= t.' names(n) ';'])));
    eval(strtrim(nchs));
end
```

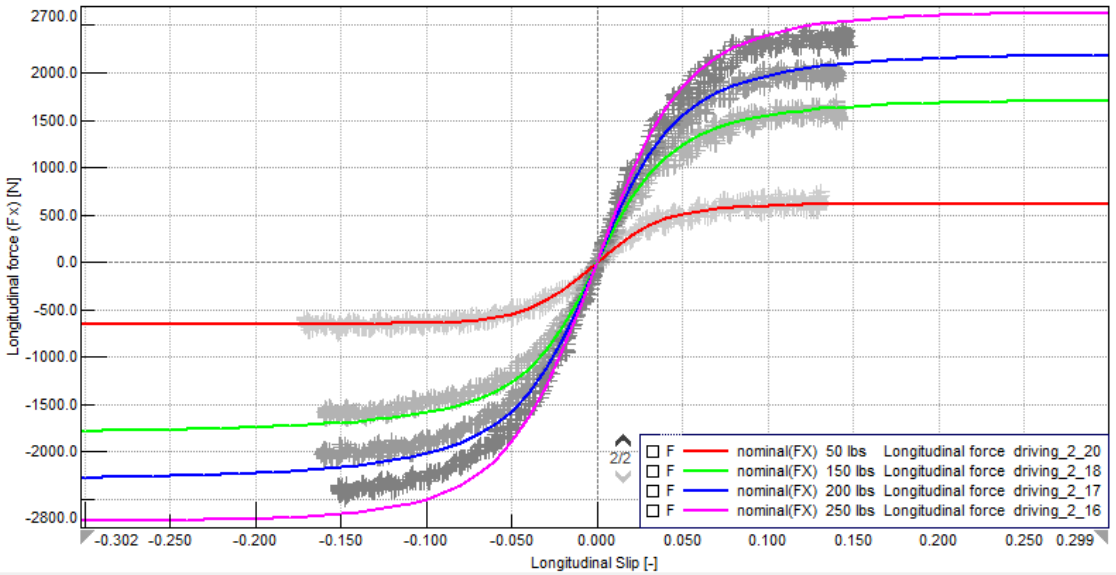
```
**MODELPARAMETERS
FITLEVEL   MF-Tool fit level key word                    FYPURE:ASW; FYPURE:CFA; FXYCOMB;
                                                         MZPURE:CMA; MZPURE:ASW; MXPURE
FZ_NOM     Tire nominal vertical load      N             667.2330
NOMPRES    Tire nominal infl. pressure     Pa            68947.600000
RFREE      Unloaded radius                 m             0.2032
TYROTIN    Tire rot. inertia about YC      kgm2          0.1218
TYRESTIN   Tire steer inertia about ZC     kgm2          0.0824
MBELT      Mass belt                       kg            1.95
```

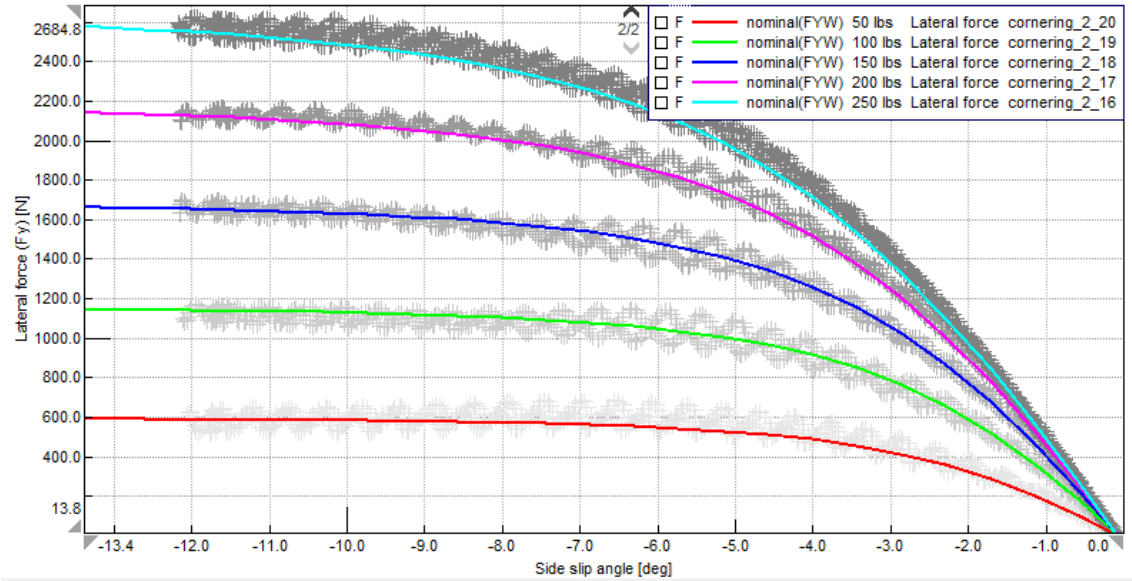
The parameters of the Magic Formula can be **fixed**, the lower and upper **boundary** can be changed, and all setup **parameters** can be **checked**.

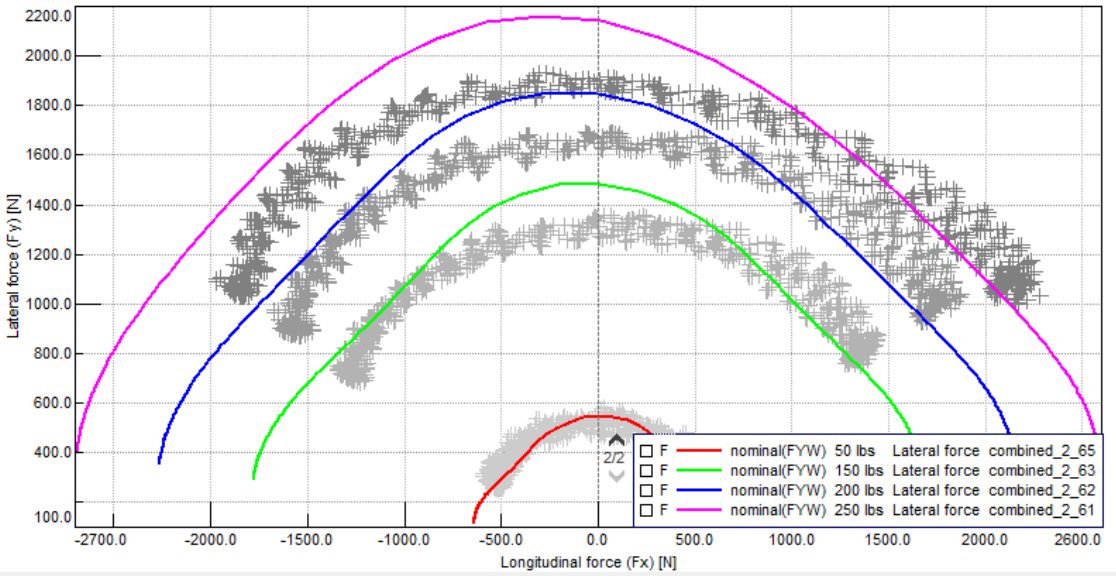


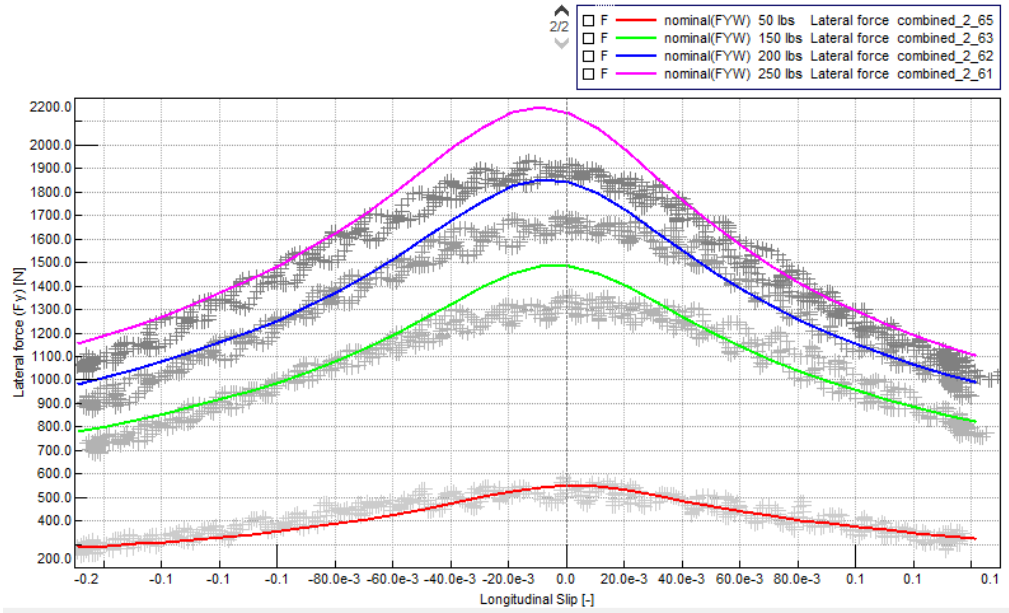


PARAMETER IDENTIFICATION









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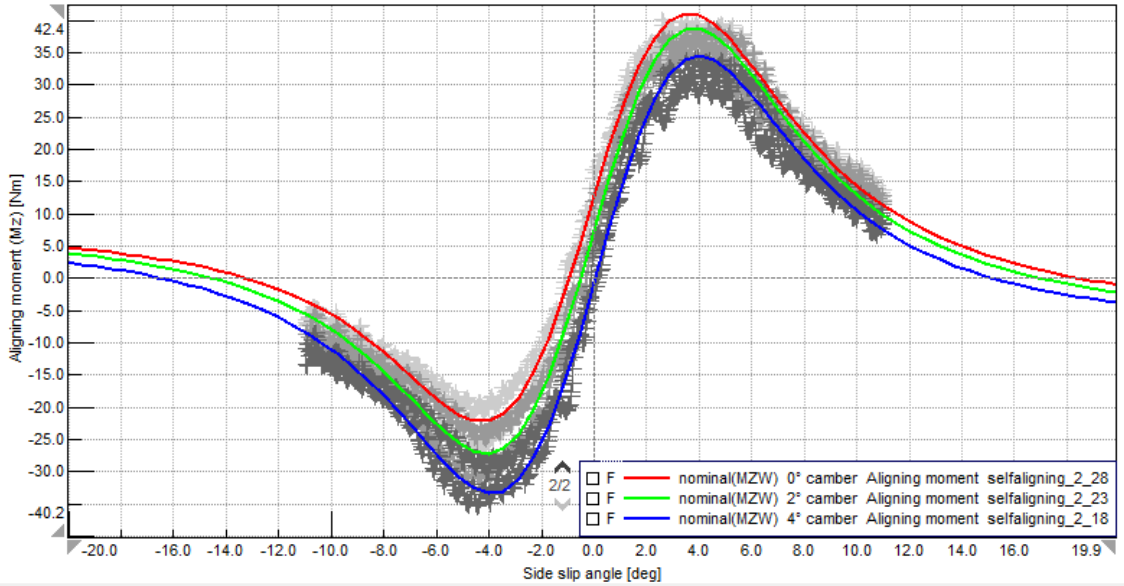

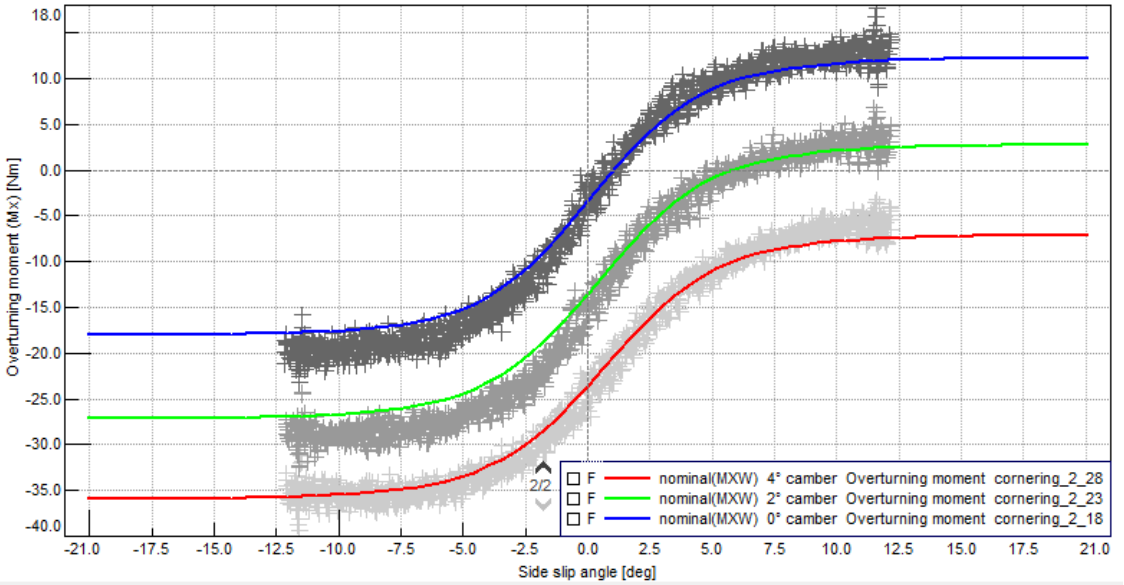

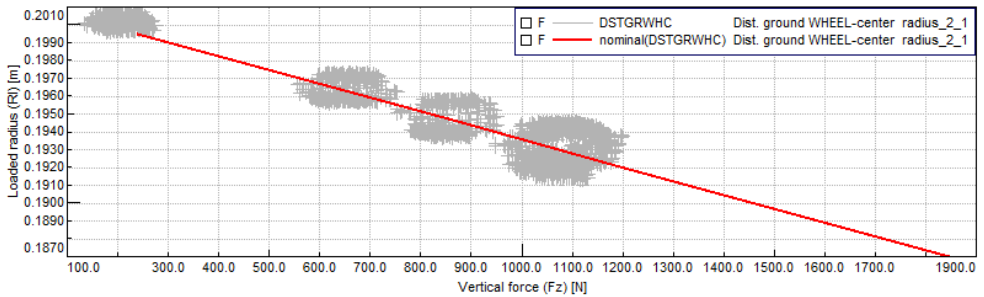

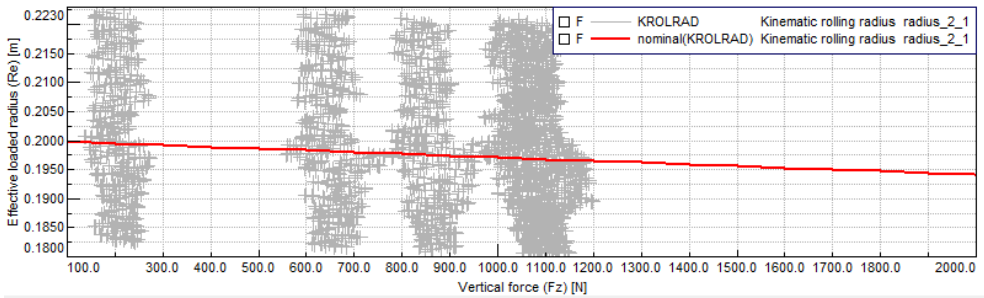

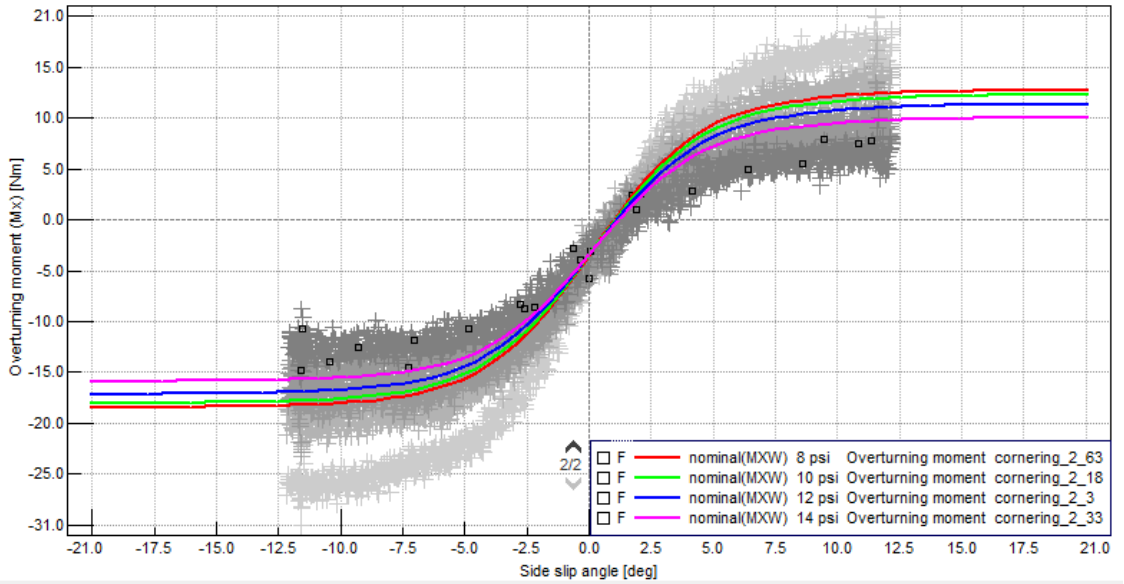

CONCLUSIONS

With these analysis a complete tyre property file is built and the kinematic of the new electric vehicle of Race UP Team can be optimised to have a better performance.

The deductions and simplifications done in this thesis work will be used by other students to describe tyres and solve their specific problems.

Thanks for the attention!

Davide Zanchetta