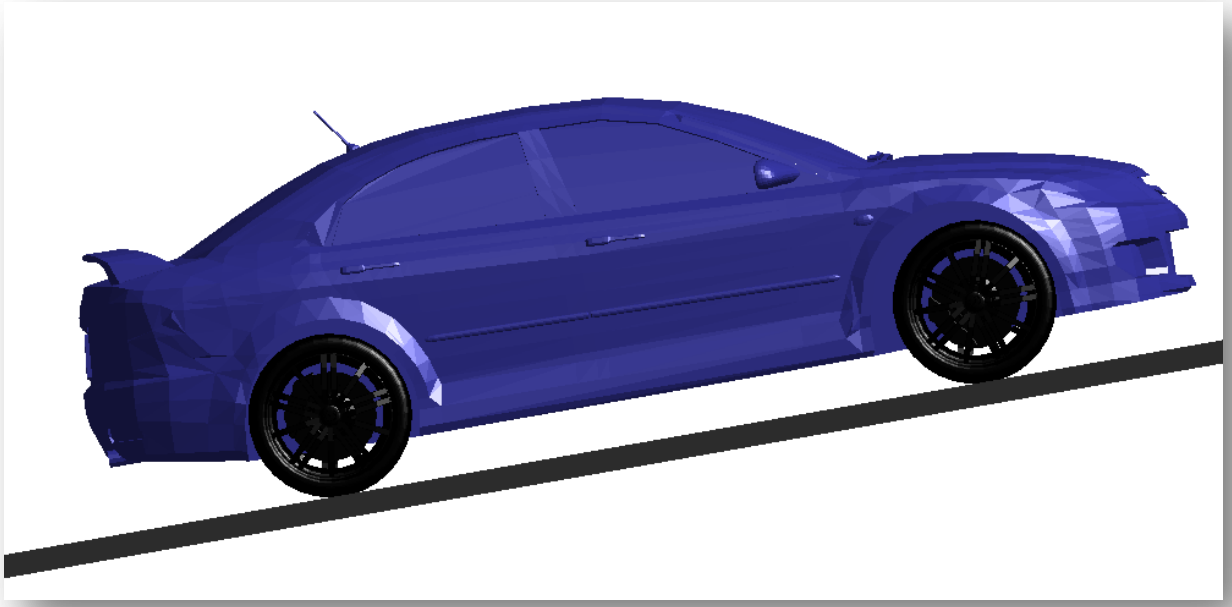
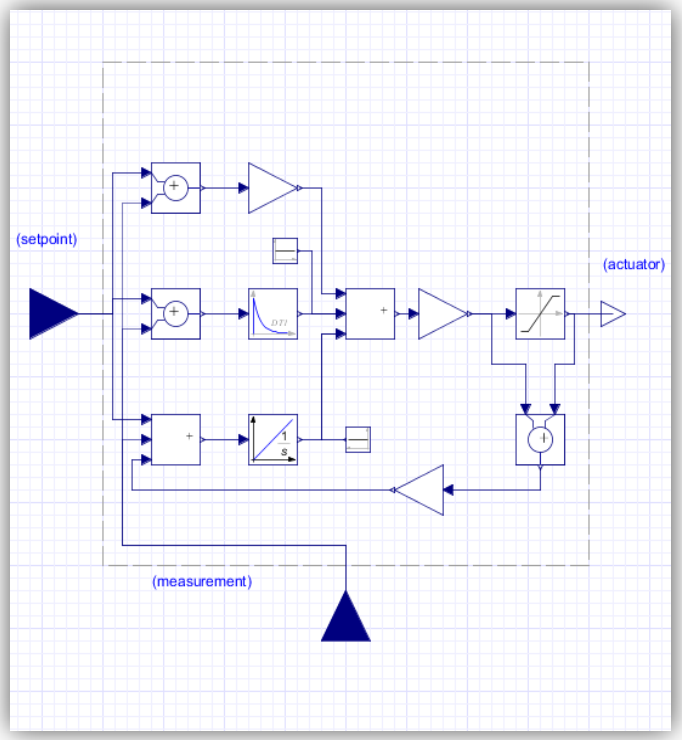
Uncertainty Analysis of Longitudinal Vehicle Dynamics with OptiY® and MapleSim®

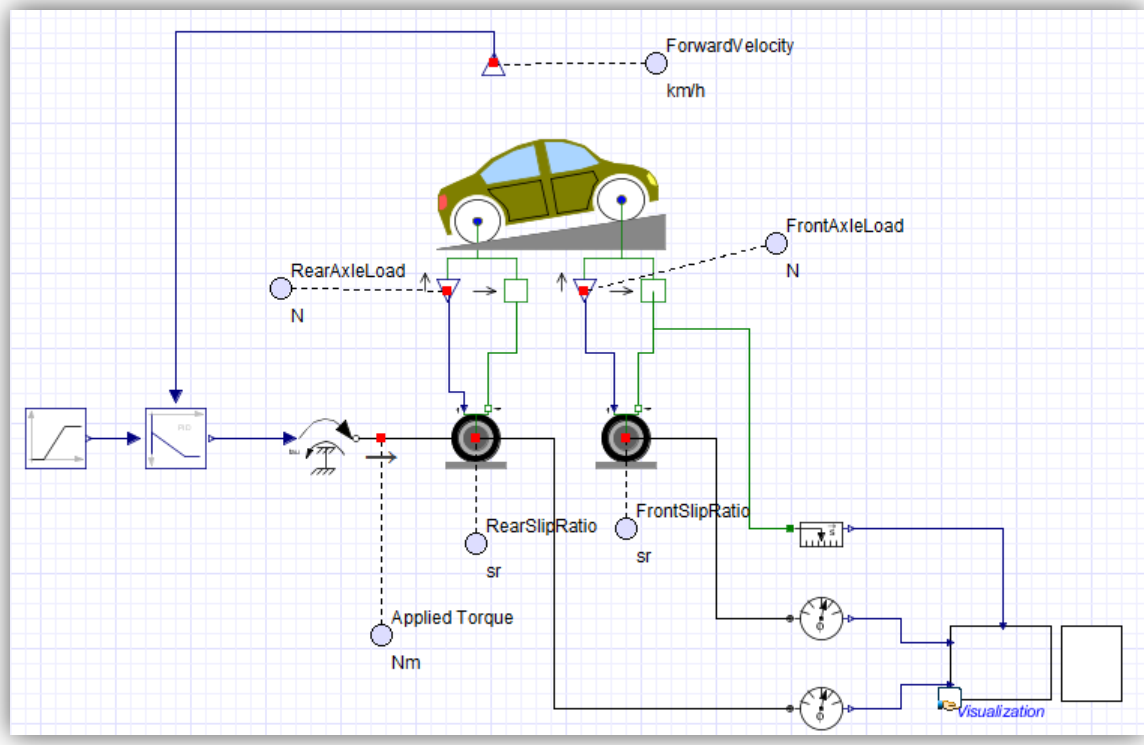


OptiY GmbH - Germany

Vehicle Dynamics with Controller in MapleSim

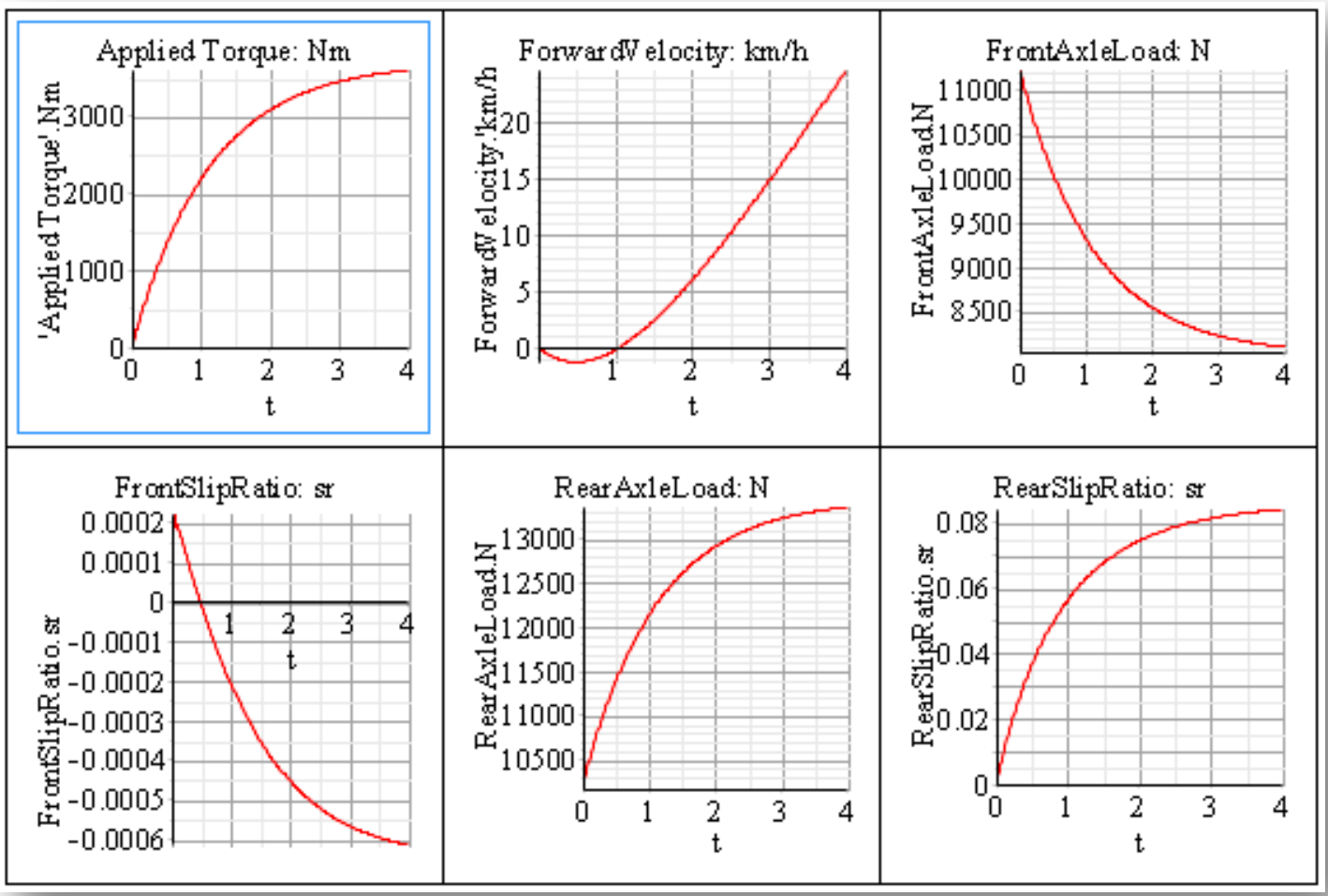


PID Controller



Longitudinal Vehicle Dynamics

Nominal Simulation in MapleSim



Design Specifications

- Specified space of design and process parameters in the table

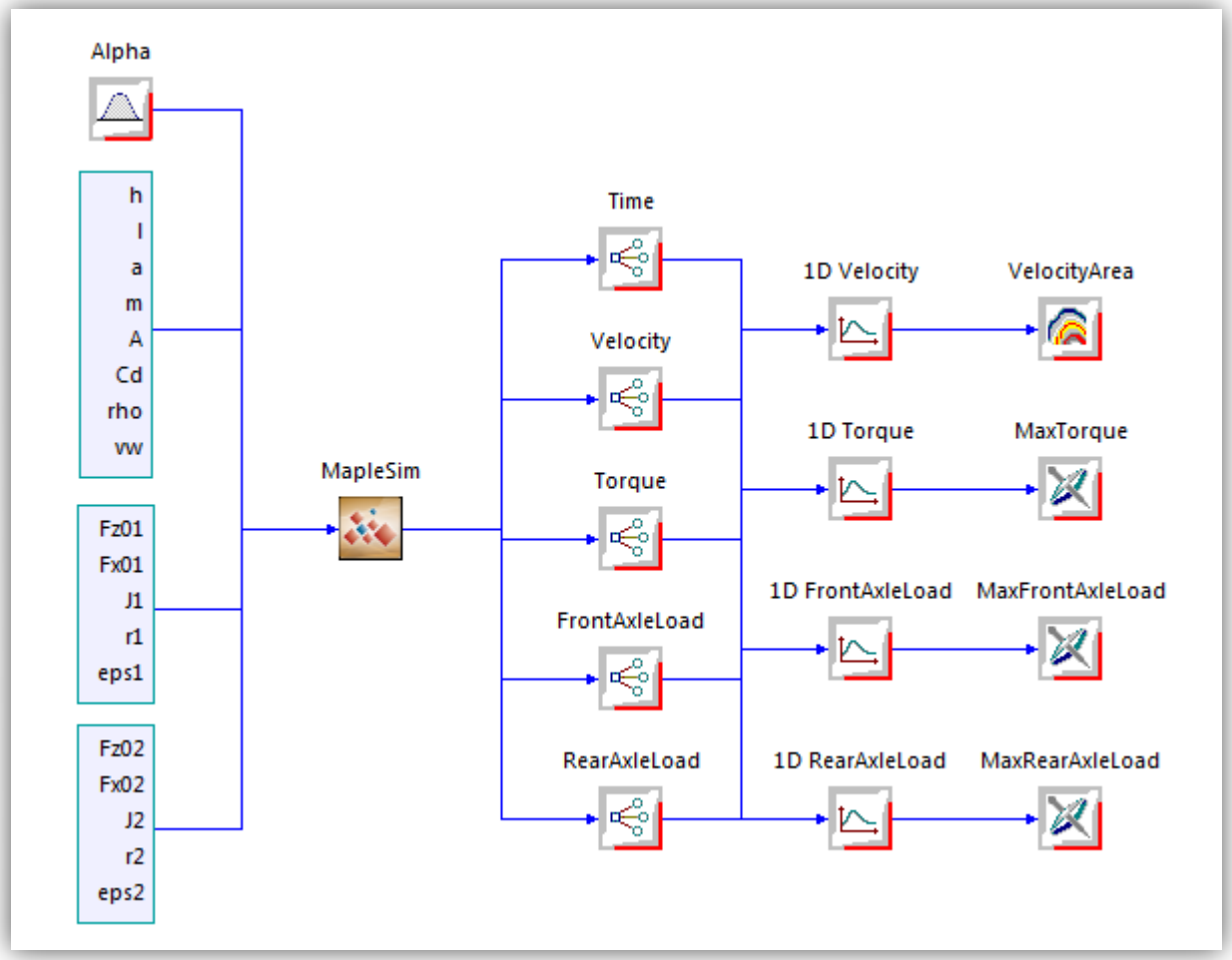
- Applied Torque < 4.000 N*m
- Front Axle Load < 14.000 N
- Rear Axle Load < 14.000 N

- Difference between target velocity and forward velocity: minimal as possible

Design Parameters

Name	Nominal	Toleran...	Unit	Comment
Alpha	10	2	deg	Ground Angle
h	0.8975	0.009	m	Ground Distance
l	2.84	0.02	m	Wheelbase
a	1.353	0.01	m	Axle Distance
m	2229	400	kg	Vehicle Mass
A	1	0.1	m^2	Cross-Section Area
Cd	0.3	0.003		Drag Coefficient
rho	1.2	0.012		
vw	-10	2		
Fz01	1500	15	N	Vertical Load
Fx01	2000	20	N	Longitutudian Force
J1	2	0.2	kg*m^2	Axle Inertia
r1	0.355	0.00355	m	Wheel Radius
eps1	0.1	0.01		Slip Ratio
Fz02	1500	15	N	Vertial Load
Fx02	2000	20	N	Longitudian Force
J2	2	0.2	kg*m^2	Axle Inertia
r2	0.355	0.00355	m	Wheel Radius
eps2	0.1	0.01		Slip Ratio

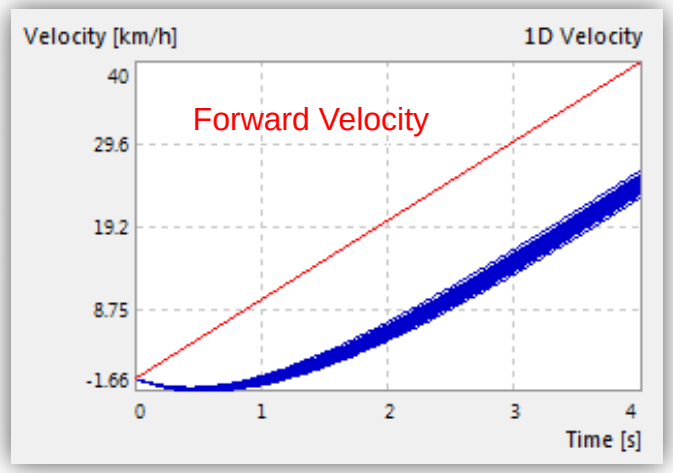
OptiY Process Work Flow for MapleSim

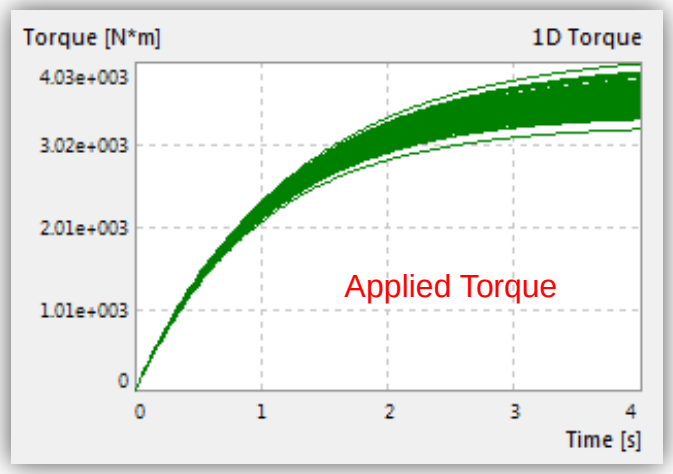


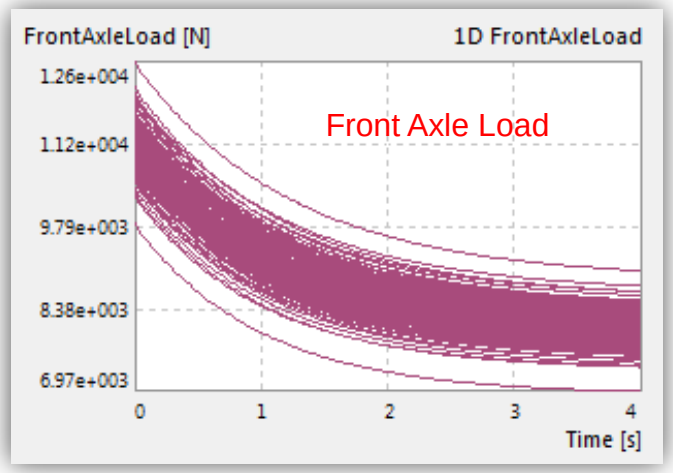
The total Space for Design and Process Parameters

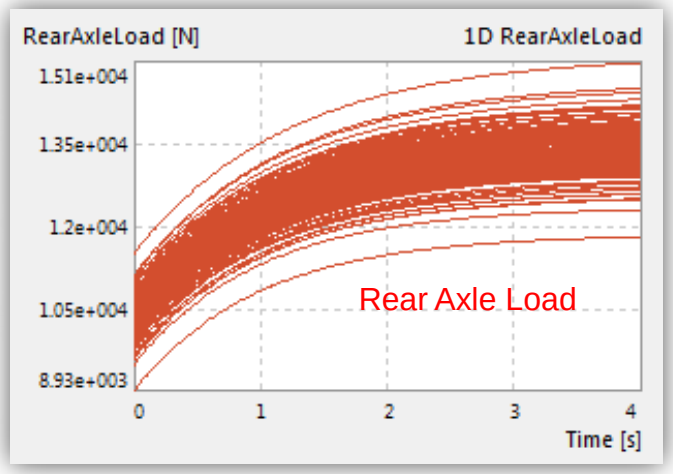
Name	Nominal	Tolerance	Distribution	Unit	Comment
Alpha	10	2	Normal Distribution	deg	Ground Angle
h	0.8975	0.009	Normal Distribution	m	Ground Distance
l	2.84	0.02	Normal Distribution	m	Wheelbase
a	1.353	0.01	Normal Distribution	m	Axle Distance
m	2229	400	Normal Distribution	kg	Vehicle Mass
A	1	0.1	Normal Distribution	m^2	Cross-Section Area
Cd	0.3	0.003	Normal Distribution		Drag Coefficient
rho	1.2	0.012	Normal Distribution		
vw	-10	2	Normal Distribution		
Fz01	1500	15	Normal Distribution	N	Vertical Load
Fx01	2000	20	Normal Distribution	N	Longitutudian Force
J1	2	0.2	Normal Distribution	kg*m^2	Axle Inertia
r1	0.355	0.0355	Normal Distribution	m	Wheel Radius
eps1	0.1	0.01	Normal Distribution		Slip Ratio
Fz02	1500	15	Normal Distribution	N	Vertial Load
Fx02	2000	20	Normal Distribution	N	Longitudian Force
J2	2	0.2	Normal Distribution	kg*m^2	Axle Inertia
r2	0.355	0.0355	Normal Distribution	m	Wheel Radius
eps2	0.1	0.01	Normal Distribution		Slip Ratio

Design of Experiment in OptiY



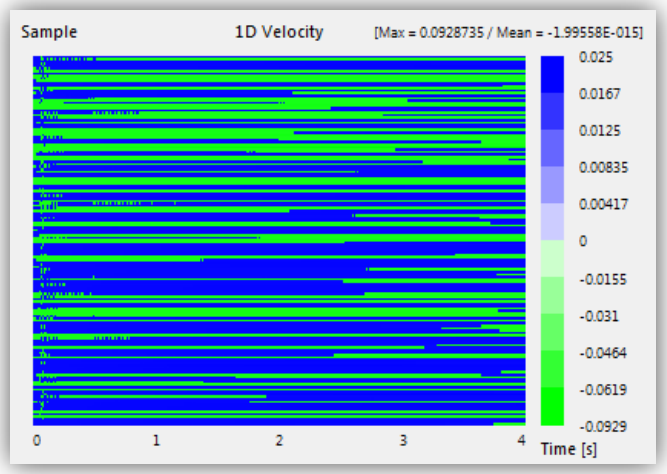


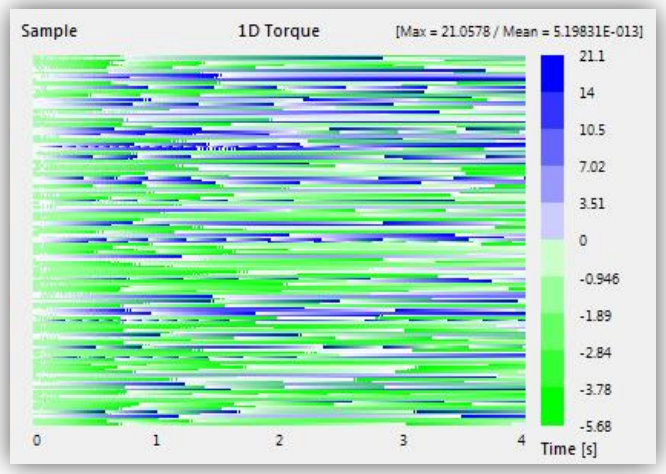


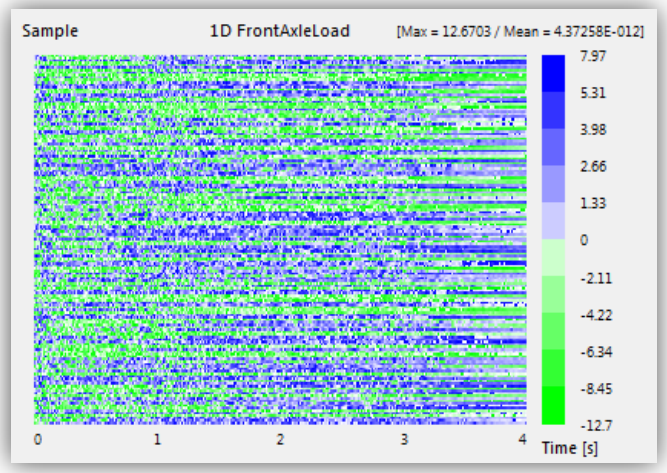


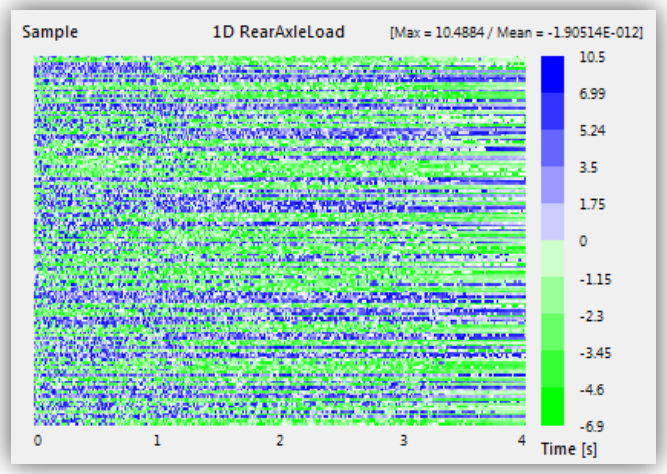
Totally 150 model calculations

Residual Plot of 1D Meta-Models

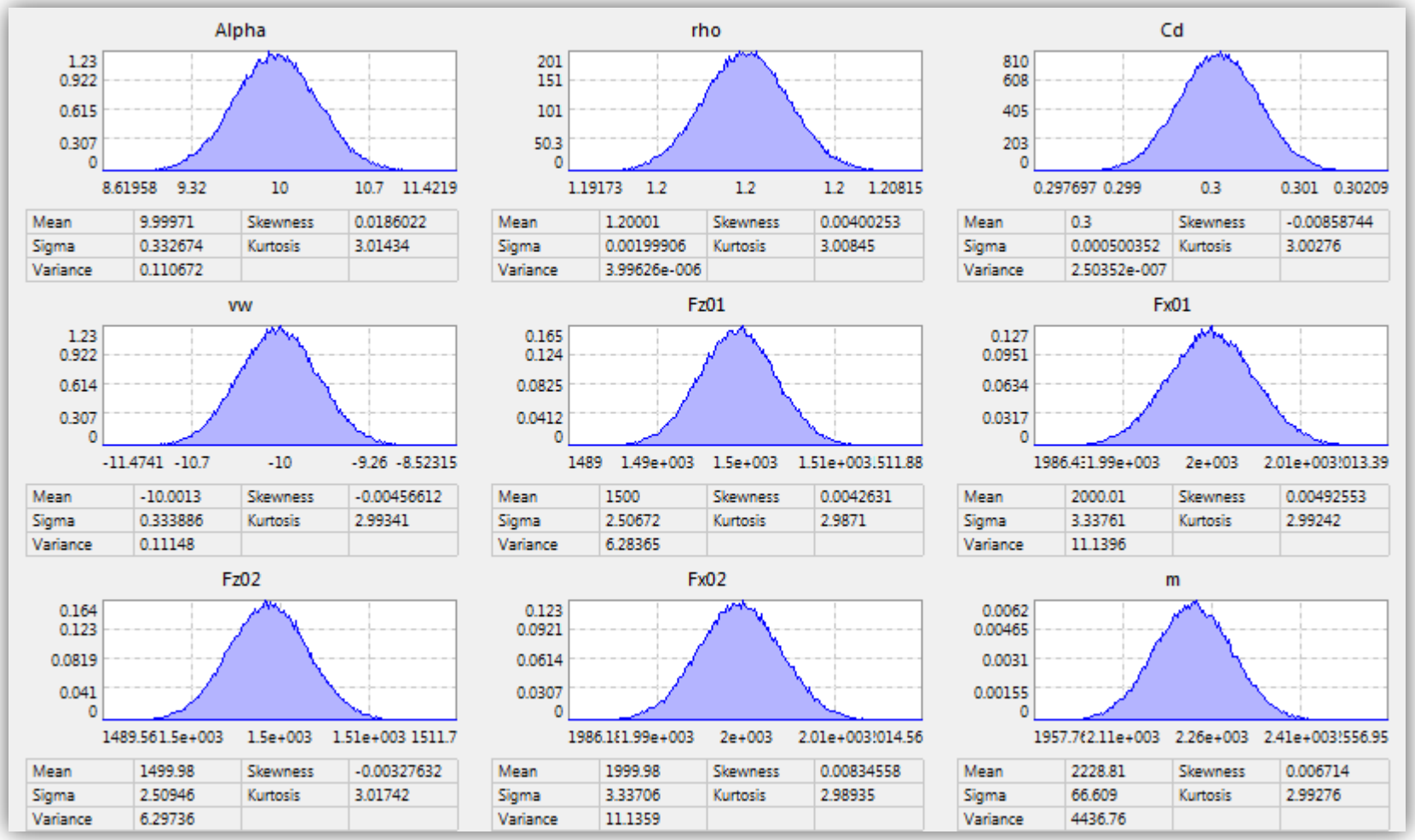






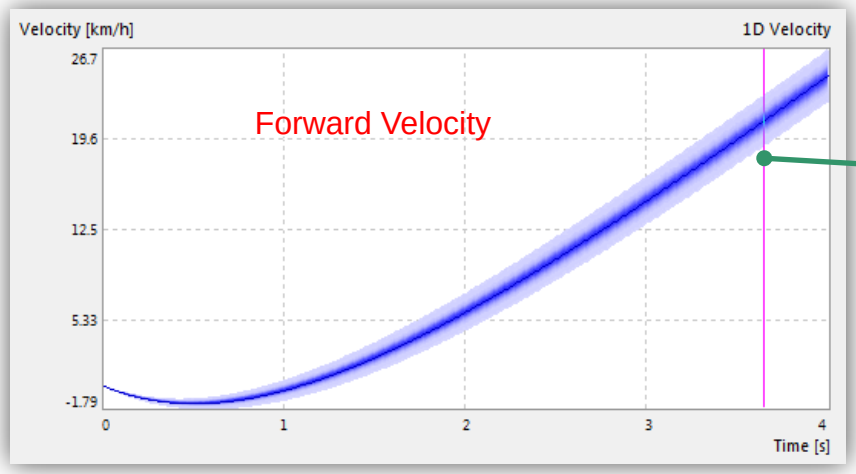


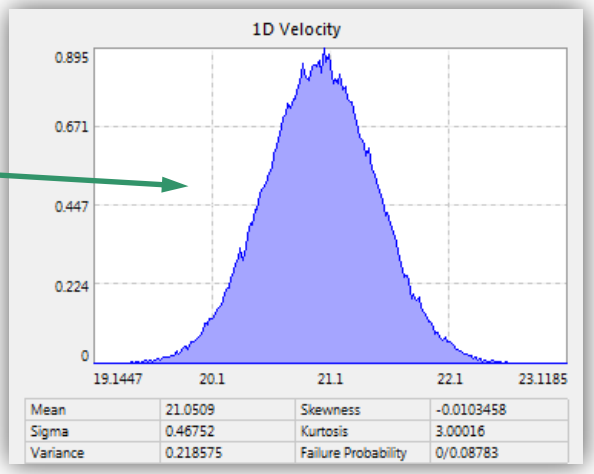
Some Design and Process Uncertainties

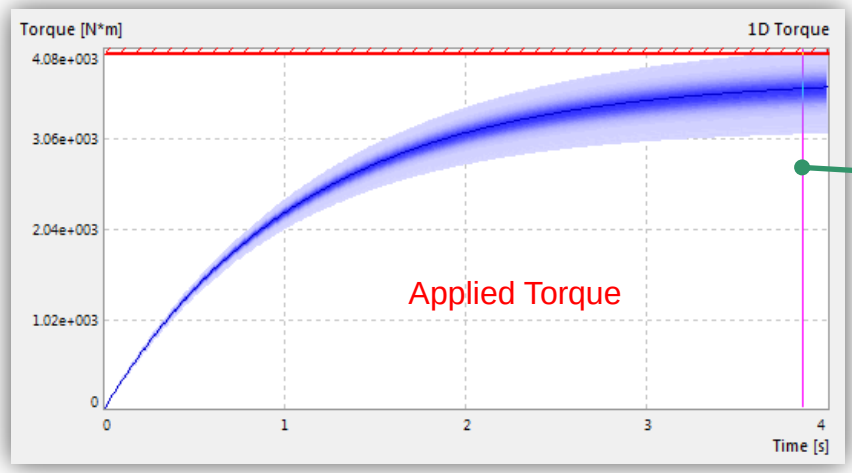


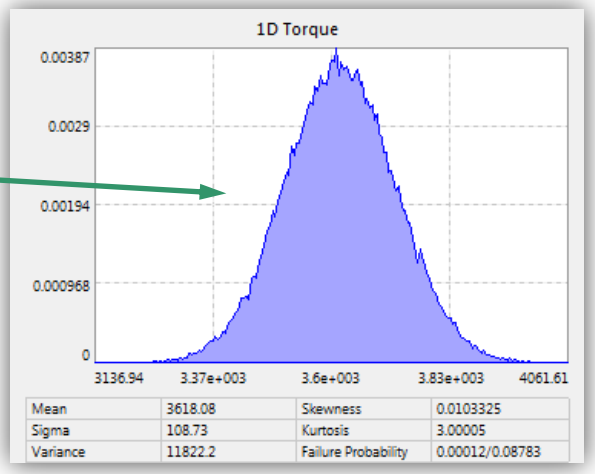
By 100.000 Samples

Probabilistic Simulation



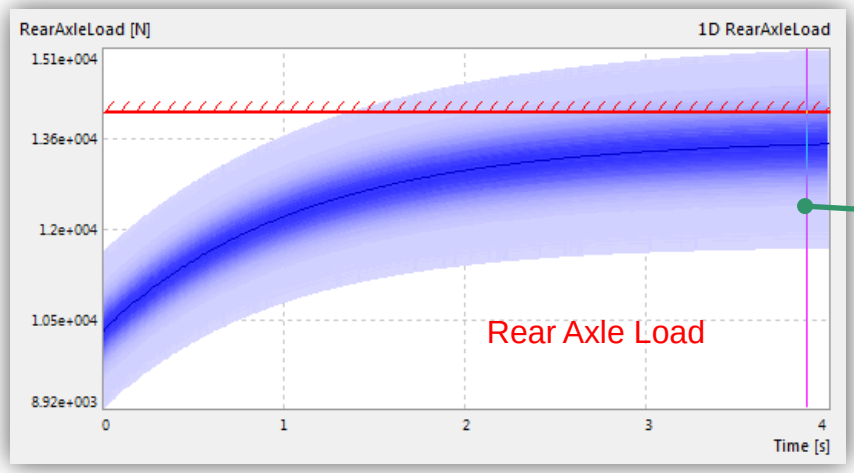


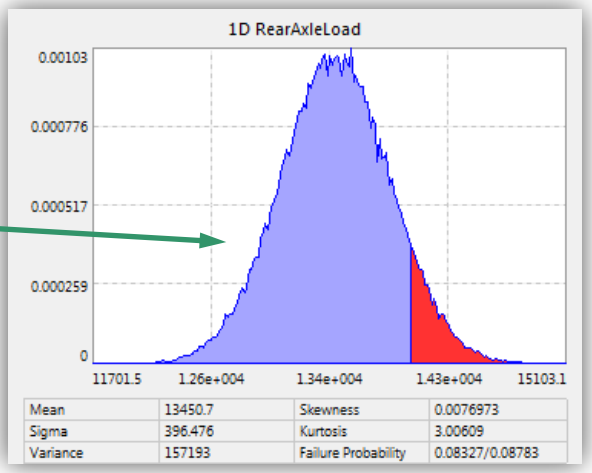


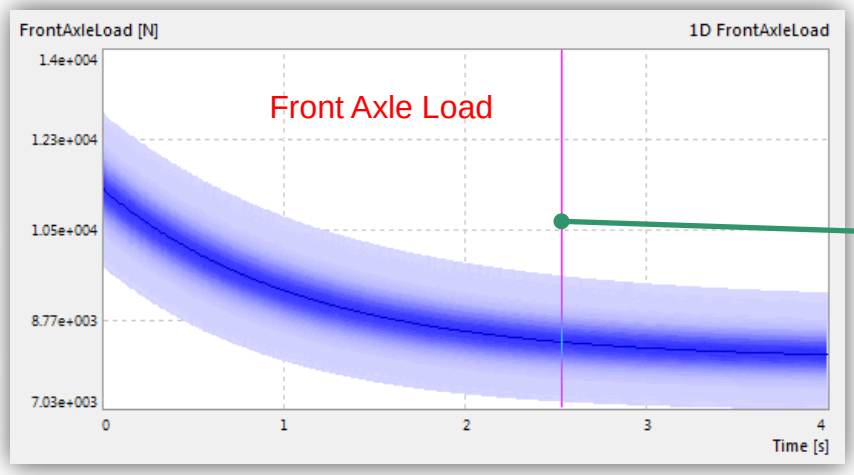


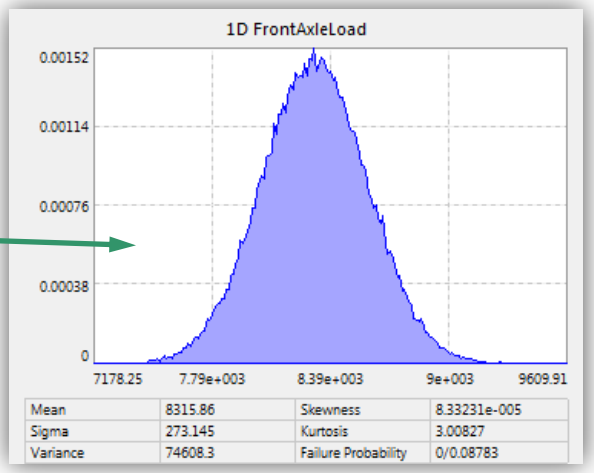
Failure Probability = 8.78%

Probabilistic Simulation



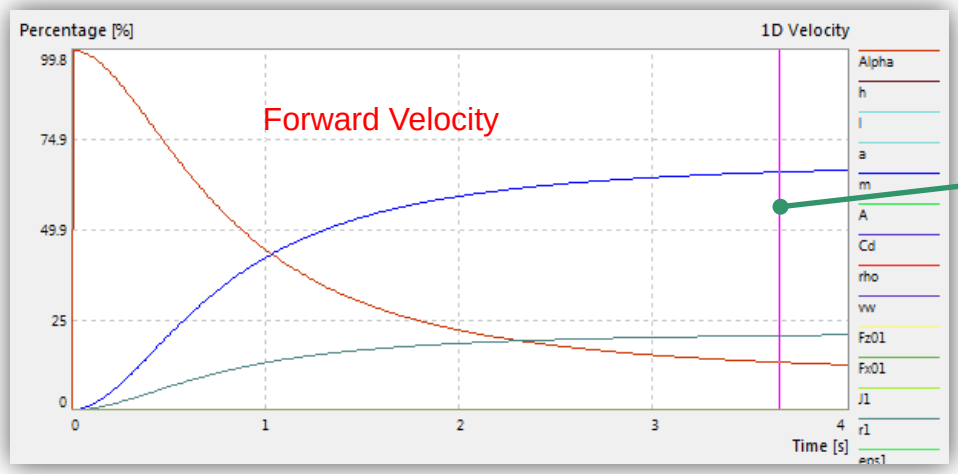


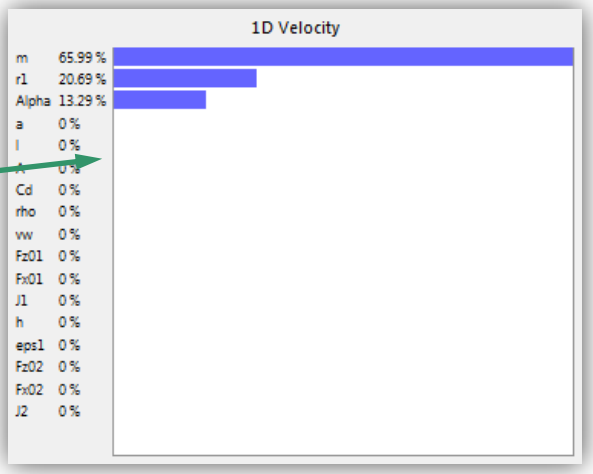


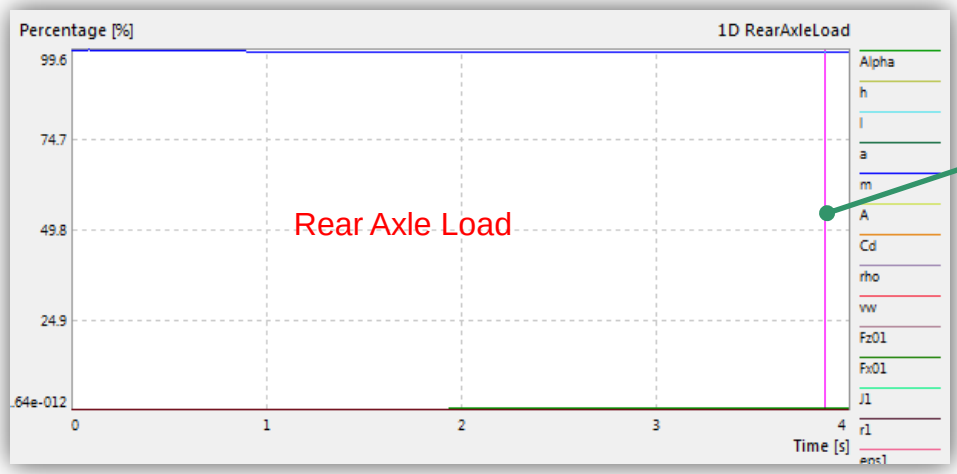


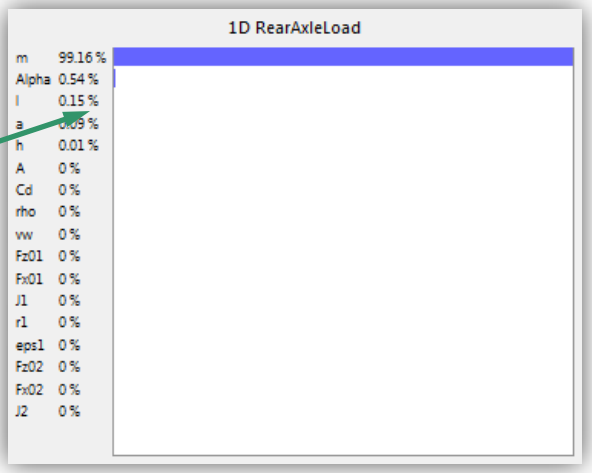
Failure Probability = 8.78%

Sensitivity Analysis

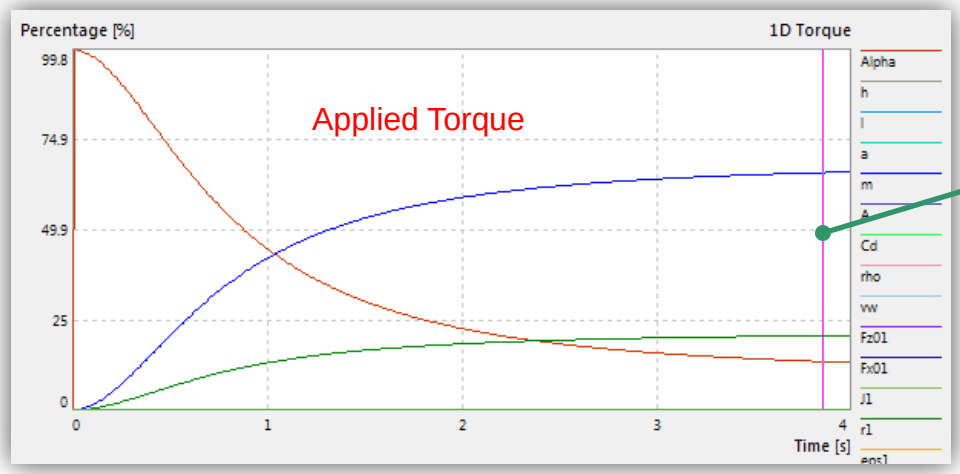


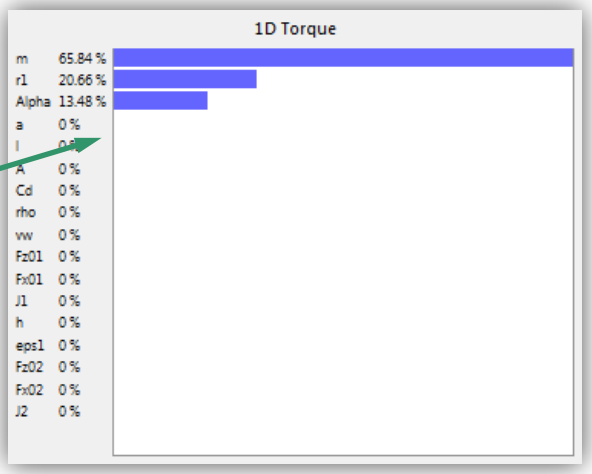


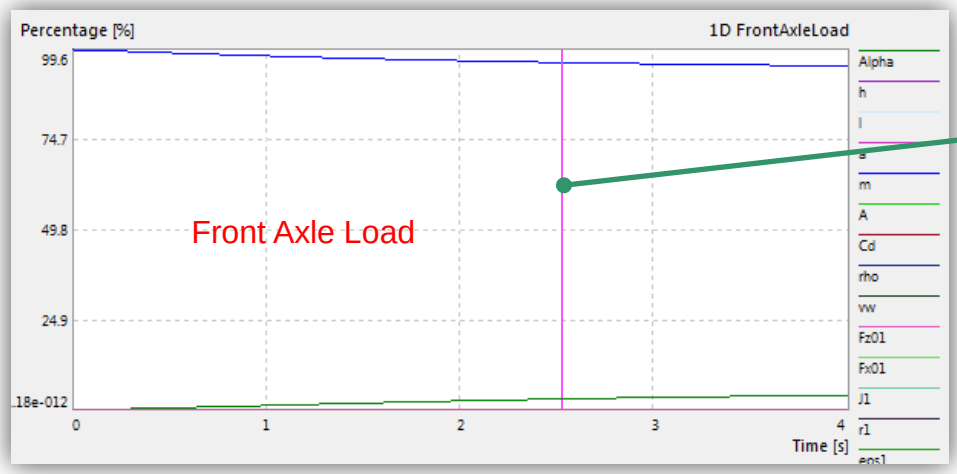


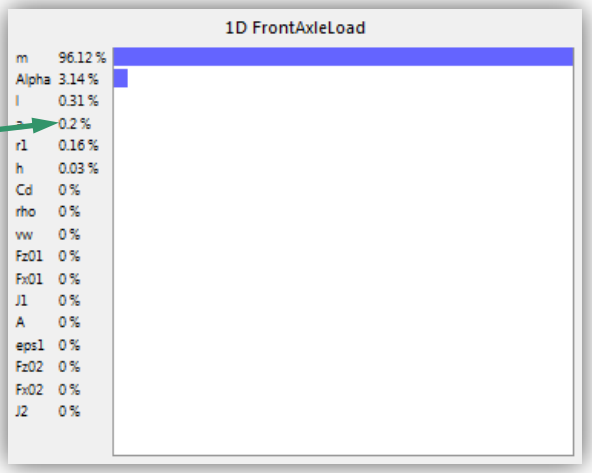


Sensitivity Analysis









Conclusion

Nominal design using classical nominal simulation cannot warranty the reliability and quality of the products, because the nominal parameters are only one fix value.

Robust design is a power-full tool for design of reliable and quality product in the early design stage without any cost. It considers parameter uncertainties as stochastic distributions.

In the case of the longitudinal vehicle dynamics, a failure probability of **8,78%** was shown for the manufacturing process

OptiY® is the leading software platform for robust design of all engineering fields using different commercial CAD/CAE-software or in-house codes.