VIRTUAL TIRE DEVELOPMENT FOR NEW ELECTRIC VEHICLE THROUGH DRIVER IN LOOP

RUTGER UIL – THE GOODYEAR TIRE & RUBBER COMPANY
GUIDO TOSOLIN – APPLUS IDIADA

CONTENTS

1. Introduction to Mahindra INGLO Platform
2. Virtual development methodology
3. Real-Time virtual models
    - Vehicle Model Generation - ADAMS to CRT Process
    - Tire Model Generation
4. Virtual development loops
5. Validation & Conclusions

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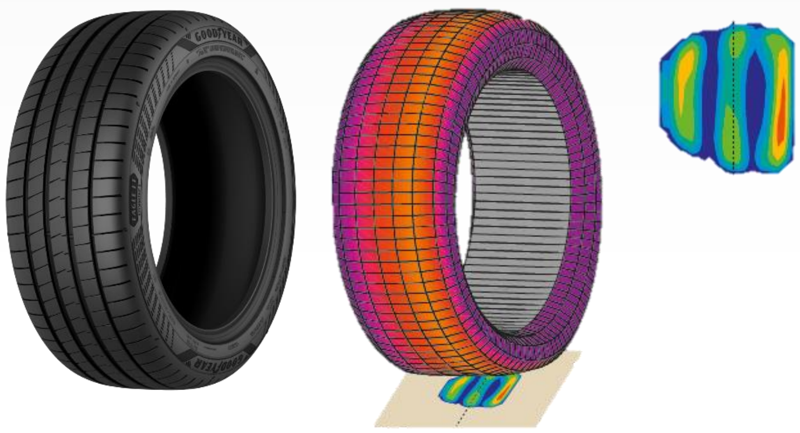
INTRODUCTION

Performance Requirements	Tire Virtual Development	Development Validation
		
Mahindra 'INGLO' New BEV platform	Virtual Tire Development Virtual modelling & assessment	Driving Simulator Virtual Evaluation Capability

MAHINDRA INGLO PLATFORM | ELECTRIC SUVS

PLATFORM HIGHLIGHTS

- Common & Modular
- 5 Different top hats
- 250+ kW dual motors
- 10.2 m TCD
- Up to 78 kWh battery
- 5 / 7 - seater

MAHINDRA INGLO PLATFORM | PERFORMANCE CHALLENGES

High RAW & CoG

Best in Class Range

Sporty Handling

Low RRC
Low Tire Noise
Best in Class Ride and Handling

Variety Road Profile

Plush Ride-comfort

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OVERALL DEVELOPMENT PLAN | VEHICLE DYNAMICS

Benchmarking & Target Setting

Soft-tool Prototypes

~~Mule Validation and Tuning~~

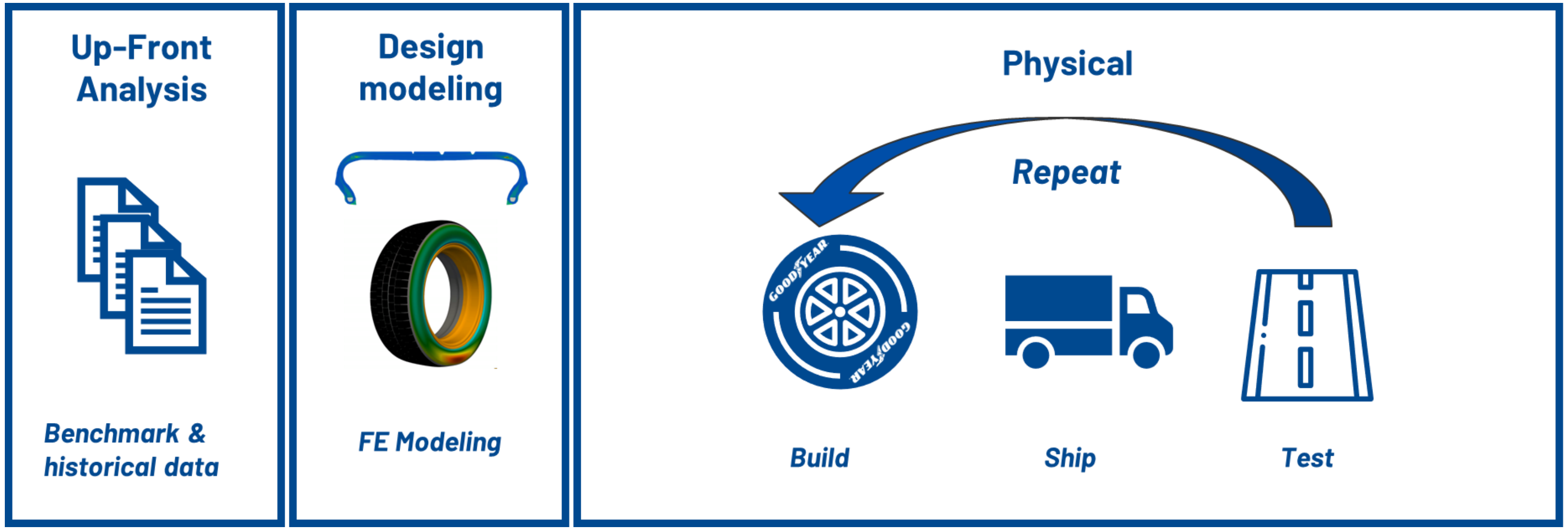
Hard-tool prototypes

Critical design decisions, normally supported by physical mule testing, to be taken with the use of driving simulator technology, including tire development.

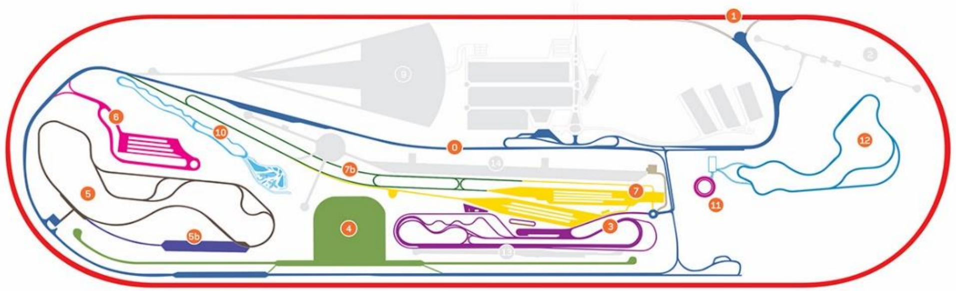
PHYSICAL DEVELOPMENT | PHYSICAL TIRE RIDE AND HANDLING

Definition: Actual prototype vehicles with latest suspension, brakes, steering parts are build to meet the vehicle ride quality and vehicle handling requirements. Subsequently, the tire submissions are subjectively evaluated on real test tracks.

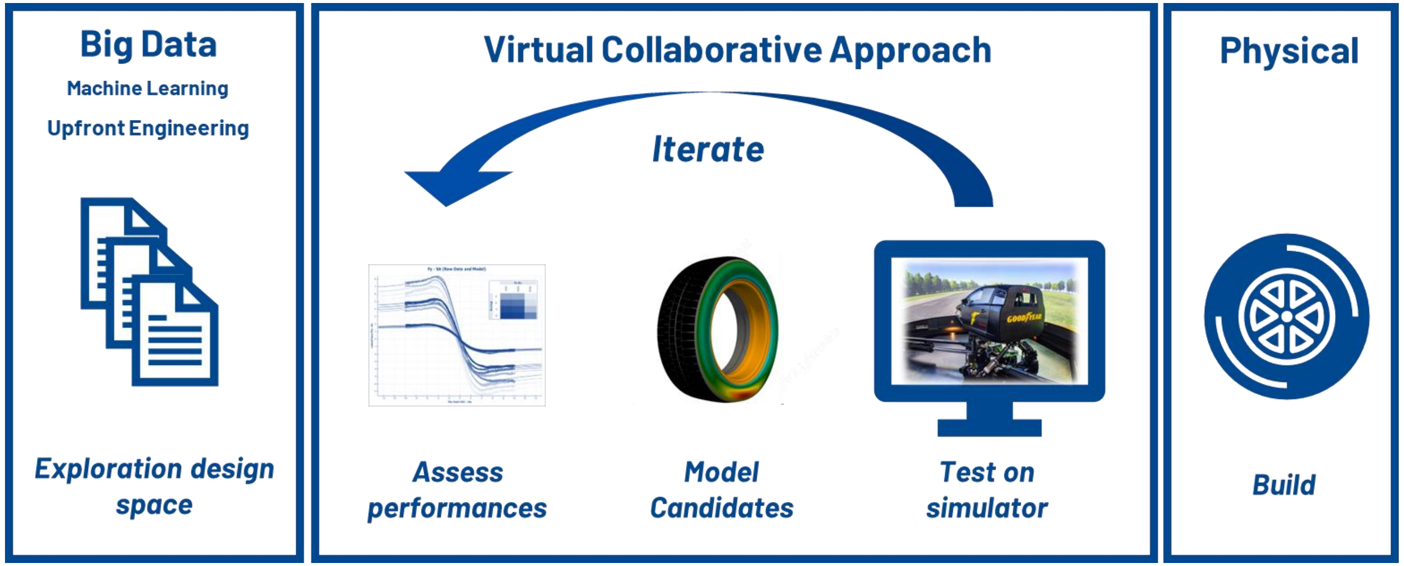
Traditional approach – Vehicle Prototype + Physical Tire Submissions + Assessment



Definition: Driving simulator is setup with latest vehicle component configurations via real-time models. In addition, virtual tire candidates enable drivers to perform a complete subjective evaluation in virtual scenarios.



Virtual approach – Real-Time Vehicle Models + Virtual Tire Models + Assessment



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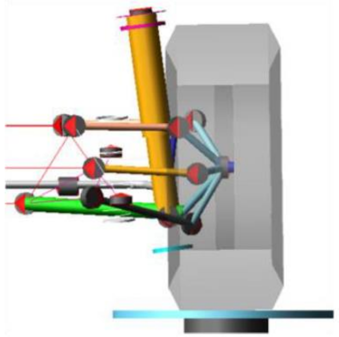
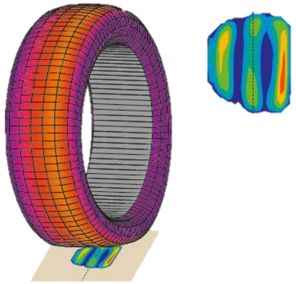
REAL-TIME MODELS | VEHICLE MODEL GENERATION



MBD model
(ADAMS Car)

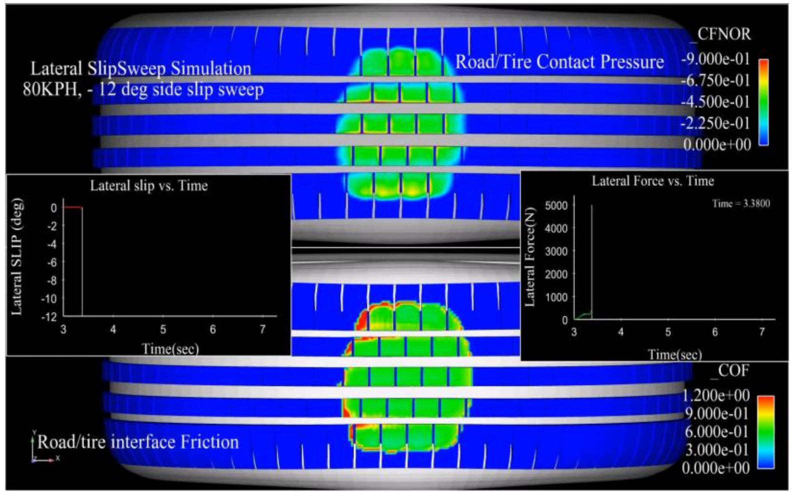
Real-time vehicle model
(VI-CRT)



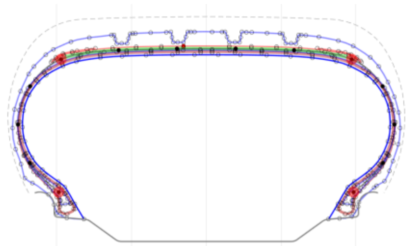
Physical tire model
(CDTire/RT)

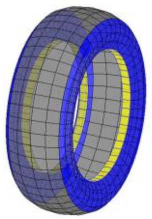
Driver-in-Loop simulator
(VI-Grade DiM250)

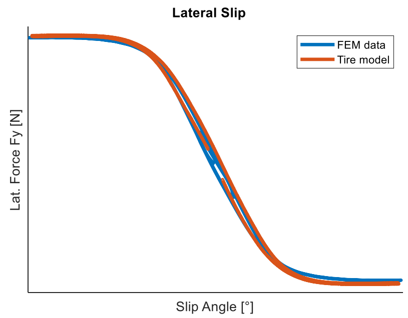
FE Simulations

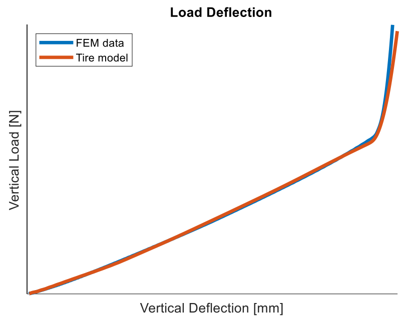


Virtual Candidates









Driver-in-Loop Simulator

PHYSICAL TIRE MODELS DERIVED FROM FE SIMULATIONS AND CONVERTED IN REAL-TIME CAPABLE MODELS FOR THE ASSESSMENT OF THE VIRTUAL TIRE PERFORMANCE

REAL-TIME MODELS | EVALUATION SCENARIOS

Attributes		Scenarios
Limit Handling Stability Understeer character		Dry Handling circuit
Steering feel Cornering confidence Lane change stability		General Highway road
Primary body motions Suspension shakes Impact forces		Deterministic surfaces Paved surface, Badly maintained road

Driver in Loop Simulator

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VIRTUAL DEVELOPMENT LOOPS | DRIVER IN LOOP ASSESSMENT

Initial driving simulator session

Objective

Set requirements for OE tire development

Methodology

1. Use reference tire model from "library"
2. Modify tire properties during DS session to understand direction of VD targets

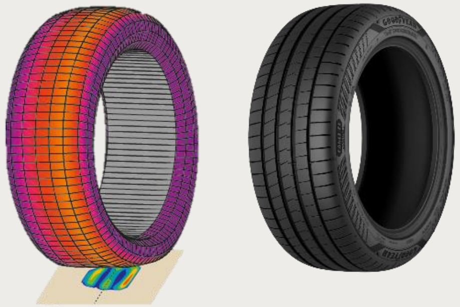
Outcome

Development focus to reach good level of yaw damping and vehicle stability.

Virtual tire submissions

Objective

Identify best virtual tire candidates that meet VD targets for Electric Vehicle



Methodology

1. Generate several FE candidates (DOE)
2. Best virtual FEA designs are converted into CD-Tire models
3. CD-Tire models are assessed in the simulator and the best candidate is selected and recommendations are provided for the next virtual loop

Outcome

Final virtual specs for prototype tires to be produced for soft-tool prototype tuning.

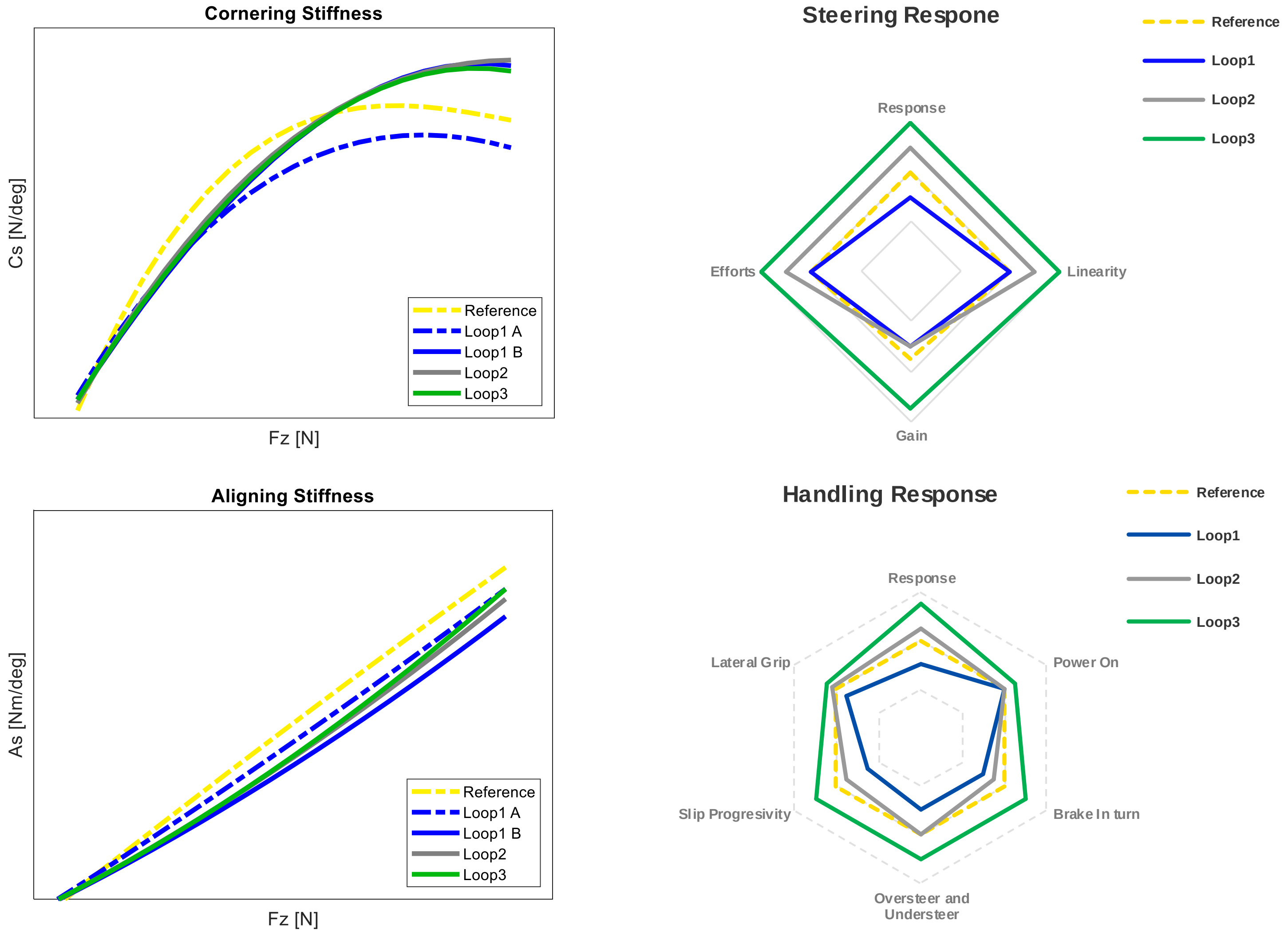
VIRTUAL DEVELOPMENT LOOPS | DRIVER IN LOOP ASSESSMENT

3 Virtual Submissions:

1 Define development direction for BEV and Ride & Handling performance.

2 Vehicle architecture updated. Improvement observed in on-center feeling and vehicle stability. Limit handling predictability to be improved.

3 Vehicle performance targets achieved. Tire characteristics and construction defined for physical build of tire prototypes.



VIRTUAL DEVELOPMENT LOOPS | OBJECTIVE VALIDATION

Test	Metric	Ref Tire	Loop 2	Loop 3
Steady-State	SWA gradient	Base	+ 13.00%	+ 19.20%
	Body Sideslip Gradient		- 8.30%	- 25.00%
Frequency Response	YawRate/SWA gain		+ 17.10%	+ 14.40%
	Frequency at max YawRate/SWA gain		+ 18.20%	+ 27.50%

During the different development loops, offline simulations were used to compliment and align with the conclusions observed in the virtual tire evaluation and the subjective feedback obtained in the Driving Simulator.

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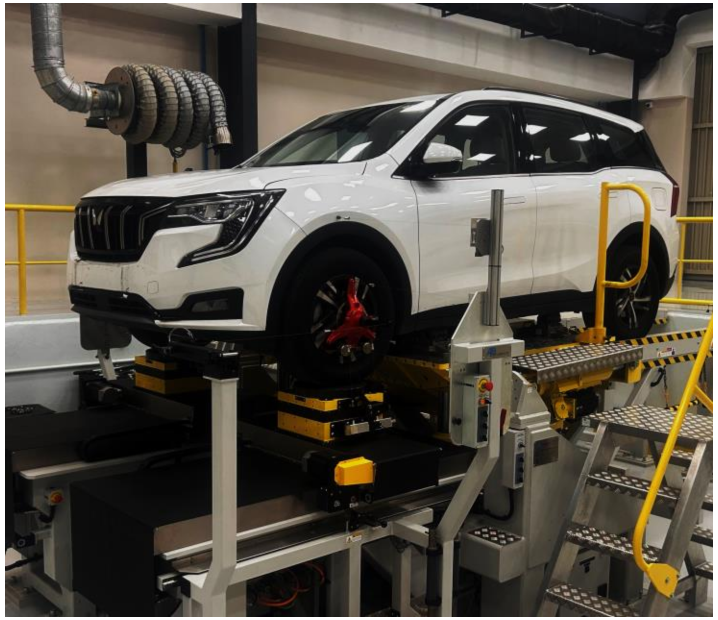
MODEL AND PROCESS VALIDATION | ACTIVITY OVERVIEW

1
Kinematics & Compliance testing



Suspension model validation

2
On-track R&H objective testing

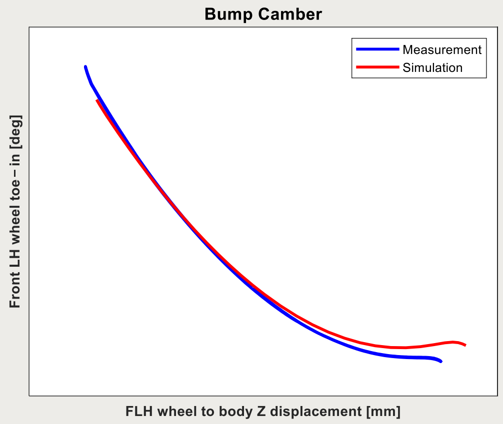
Complete vehicle model validation

3
Subjective evaluation

Compare subjective assessment of the real vehicle vs driving simulator

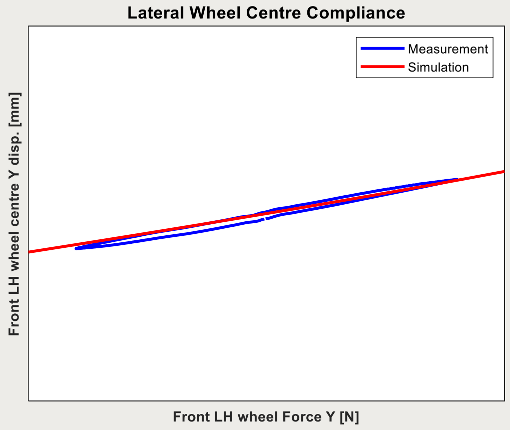
MODEL AND PROCESS VALIDATION | OBJECTIVE VALIDATION RESULTS

SUSPENSION LEVEL



Kinematics

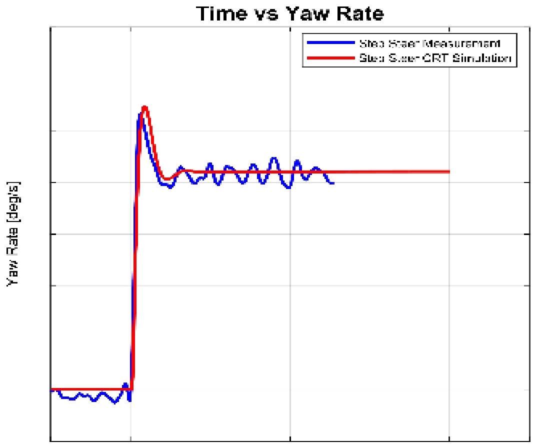
~ 95%



Compliance

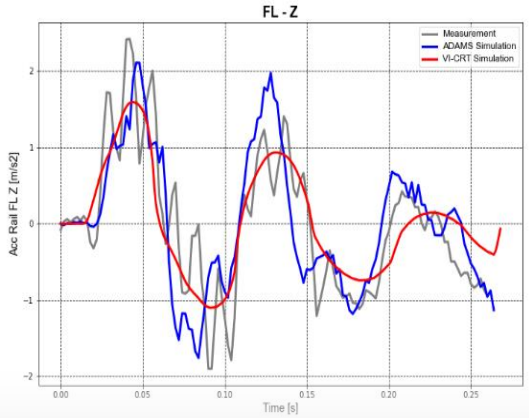
~ 95%

COMPLETE VEHICLE LEVEL



Handling & Primary ride

~ 90%



Secondary ride

~ 70%

CONCLUSIONS

- During three virtual submissions using driver-in-loop simulator, a **significant improvement** is observed in vehicle level performance, in terms of handling and steering attributes.
- Good correlation observed between objective measurements on prototype vehicle compared to virtual simulation model.
- Similarly, the tuning engineers confirmed that the behavior of the prototype vehicle was well aligned with the feeling in the simulator.
- This establishes sufficient confidence that **virtual models used are representative of physical behavior** and virtual tire development can successfully be incorporated into mainstream product development life cycle.
- This methodology allows to identify critical areas of improvement for vehicle level performance at an early stage of the project and allows tire manufacturers to define tire characteristics suitable for vehicle requirements.

SPORT UTILITY VEHICLES

THANK YOU

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