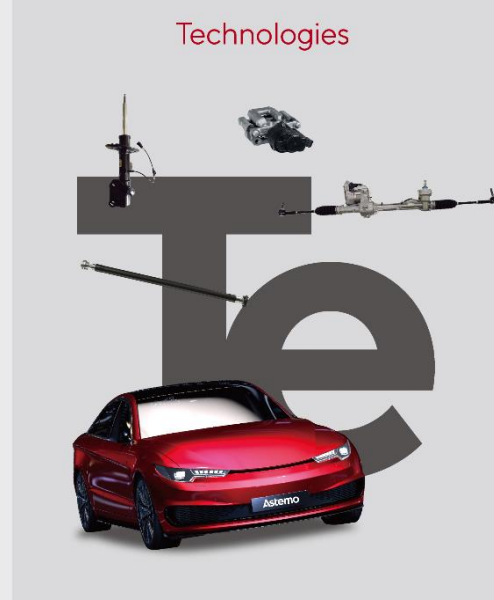




HITACHI
Inspire the Next

AI-MBD Damper Model Integration

Applying deep learning methods to improve damper models

Omar Elsewify

Murilo Junqueira

Claudio Fernandes

Adv. Chassis Development / Vehicle Dynamics

Suspension BU

Hitachi Astemo Americas, Inc.

June 16th, 2024

Astemo

Hitachi Automotive Systems

KEIHIN

SHOWA

NISSIN

are integrated to be

Hitachi Astemo

Powertrain Systems

Chassis Systems

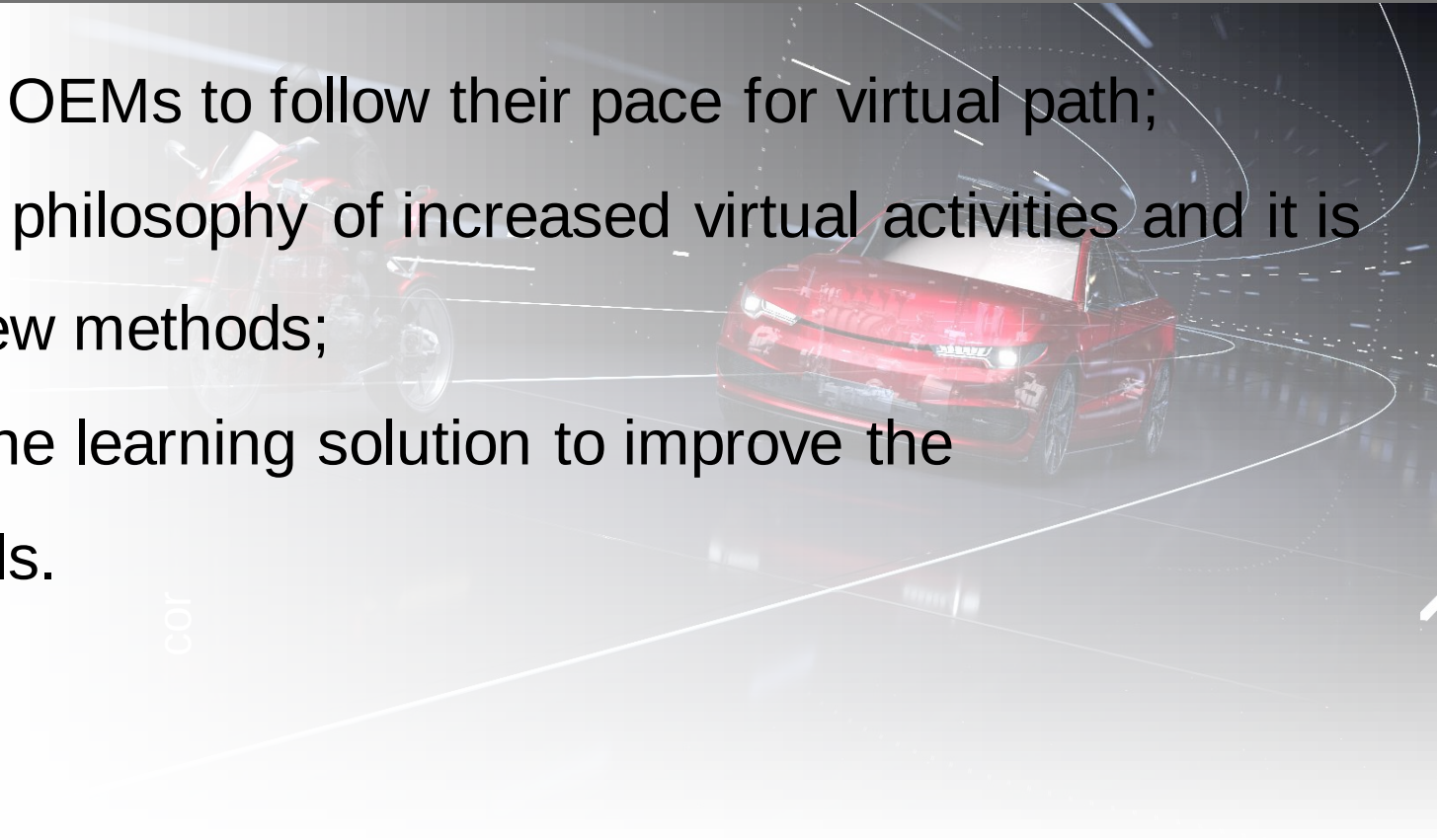
Motorcycle Systems

Autonomous Driving/Advanced Driver Assistance Systems

Astemo

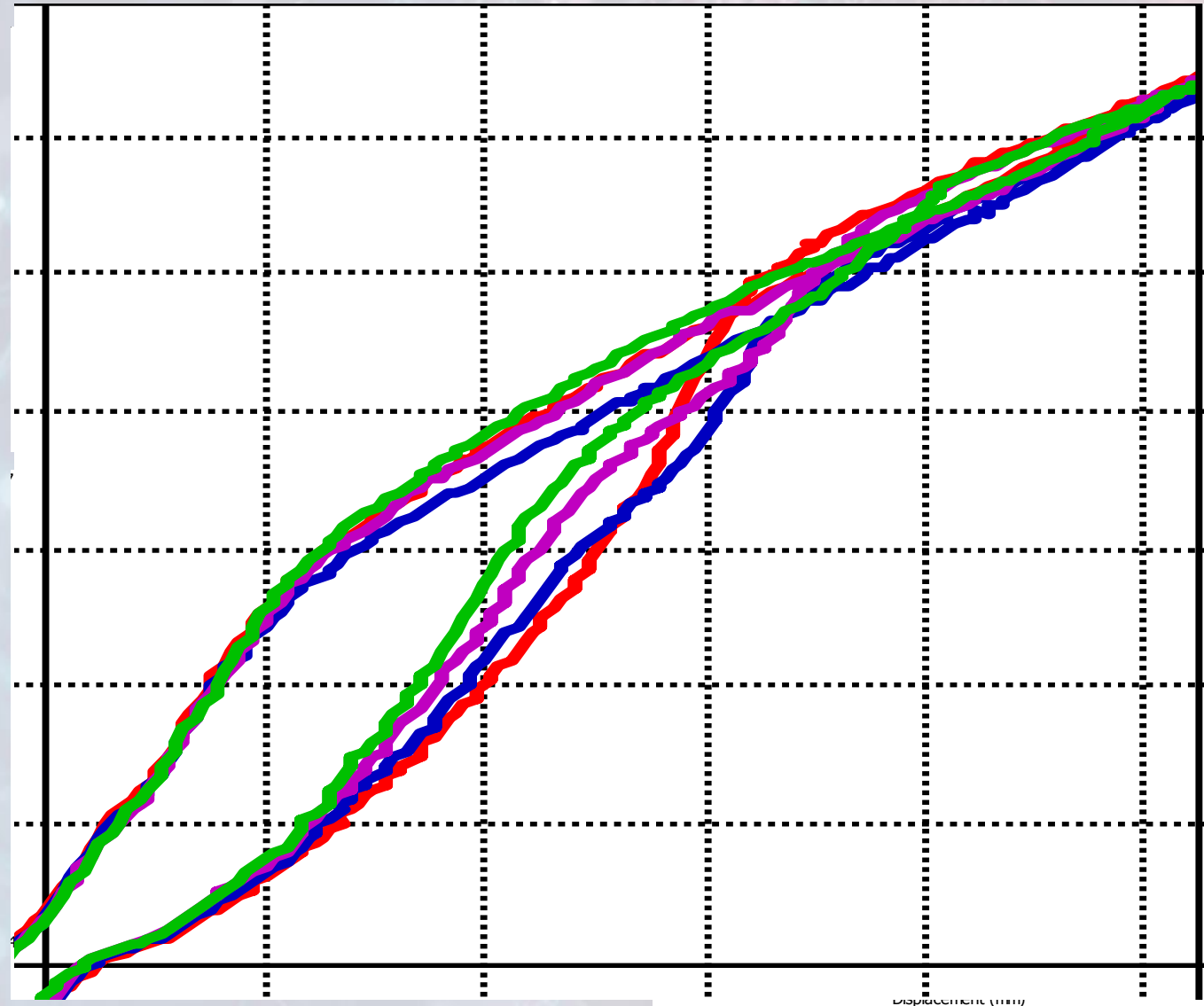
Advanced
Sustainable
Technologies
for Mobility

- Tier1 suppliers are being pushed by OEMs to follow their pace for virtual path;
- Astemo has being pro-active on this philosophy of increased virtual activities and it is investing on tools and developing new methods;
- One of this new methods is a machine learning solution to improve the representativeness of damper models.



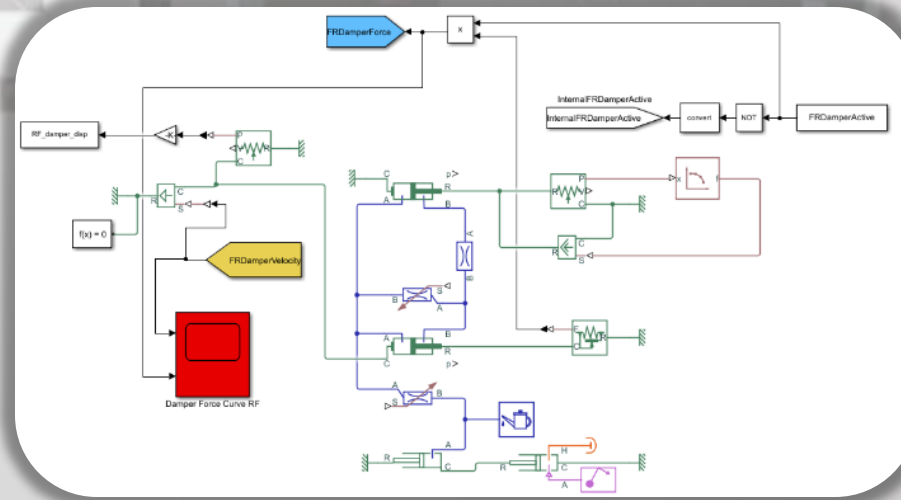
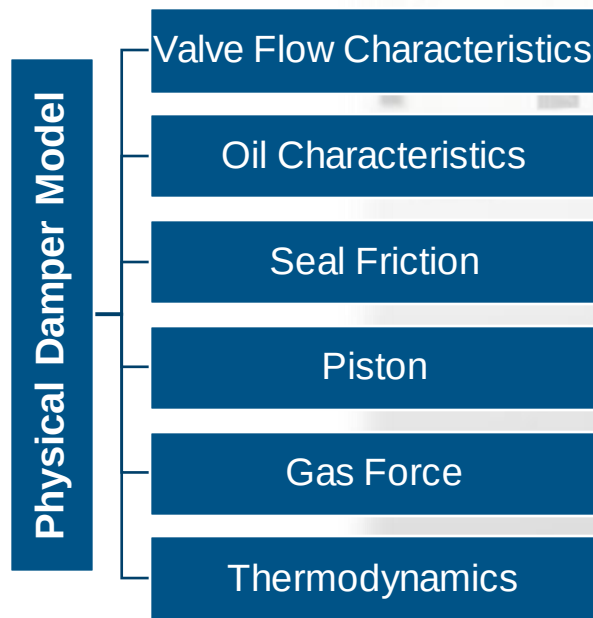
Current Standard of Damper Model – Lookup Table

- The lookup table → standard tool for most OEMs
- Normally taken from 7-speed test
- Quite often, different dampers setup are achieved with a same 7-speed values at zero displacement (**same lookup tables**)
- 7-speed test as well as a look-up table (even when expanded to a 3D table) does not cover important damper behavior – e.g. hysteresis



Alternative Damper Model – Physical Model

- Physical damper modelling is an alternative to lookup tables
- Requires representing **each component** individually in the model
- Sometimes the representation is also a simplification of a complex phenomenon

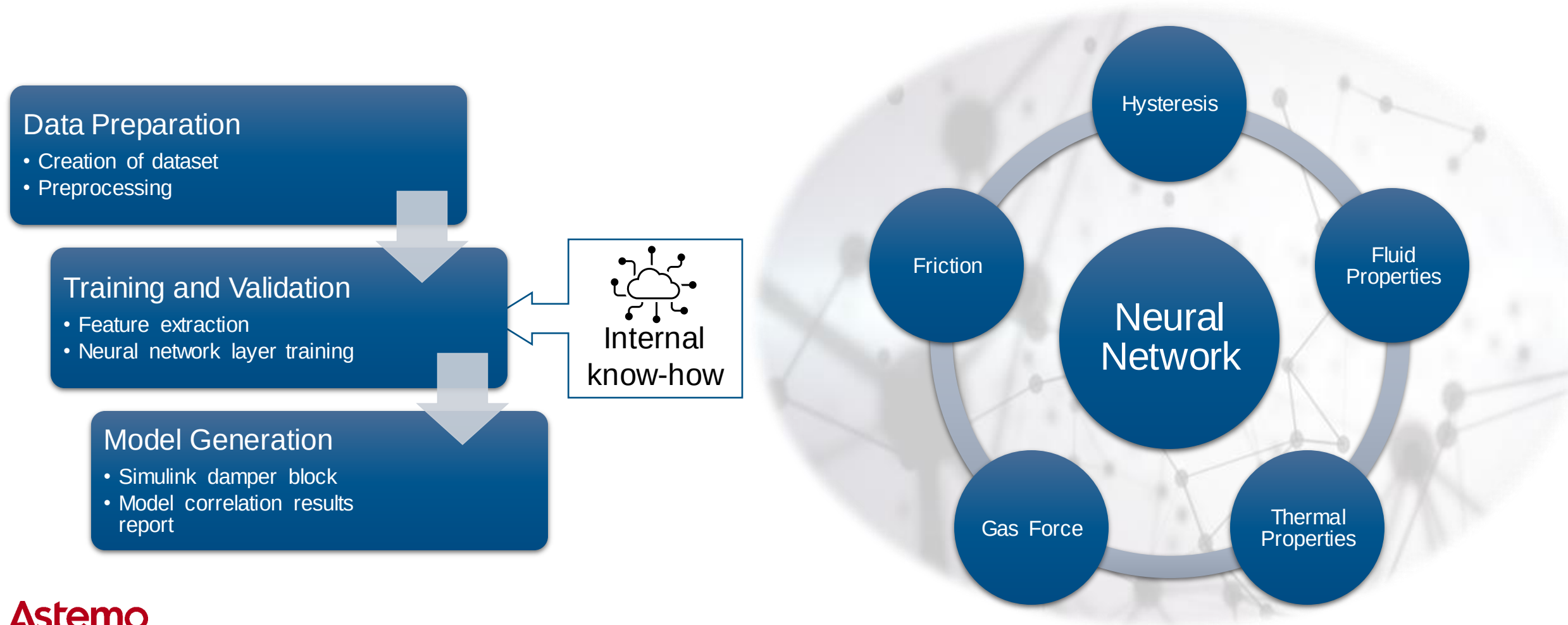


Issues with Physical Models

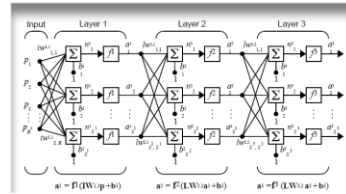
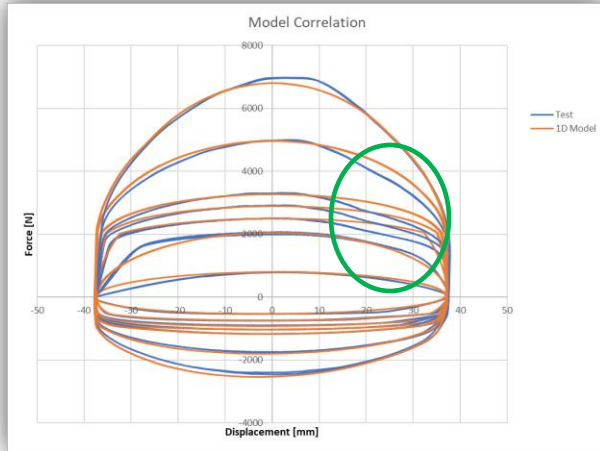
- Complexity
- Knowledge of System
- Lack of Generality
- Compute Power
- Parameterization

Deep Learning Damper Model Solution

The solution from Hitachi Astemo addresses these lookup table prediction weaknesses, by offering a trained neural network model able to pick up trends in damping force from mass training datasets and internal know-how.



Model history inside Astemo

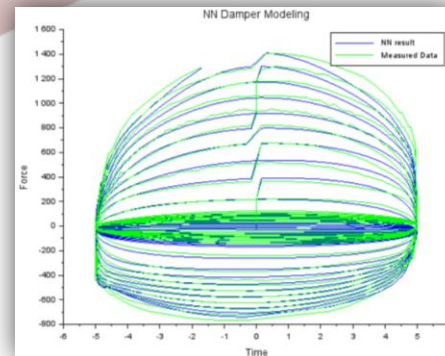


- Own code developed
- Simple inputs (velocity and displacements)
- Initial test procedure implemented

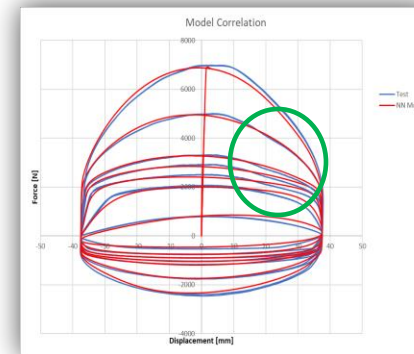


- Enhanced learning
- Multi-variable (inputs)
- Improved testing procedure

1st gen. Deep Learning models

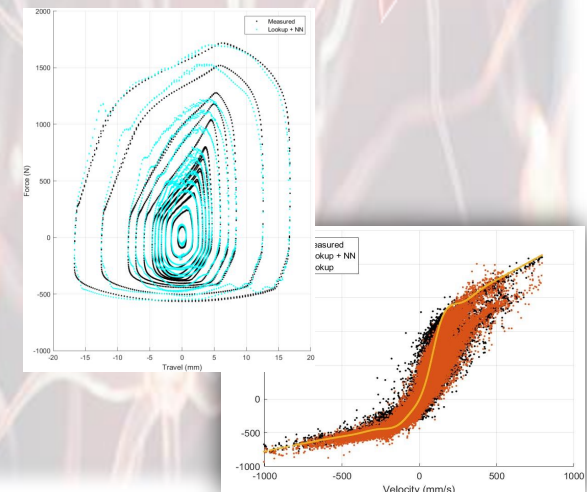


2nd gen. AI-MBD



- Neural Network working in parallel with an engineering models
- Deep learning functions increasing model fidelity
- While incorporating ASTEMO internal know-how
- Model wrapped under license

3rd gen. AI-MBD (Hybrid)

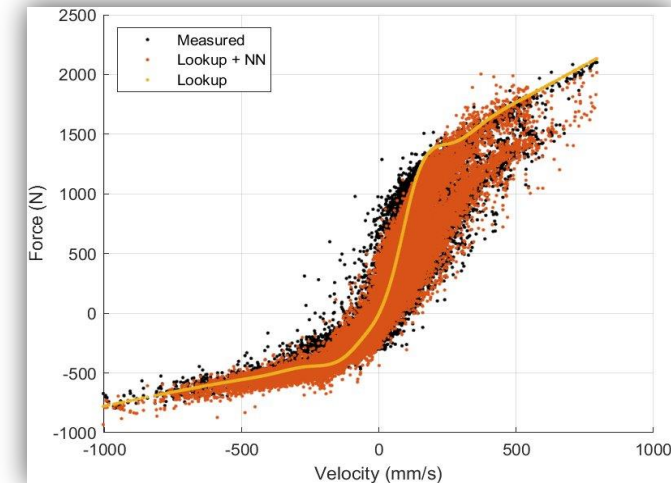
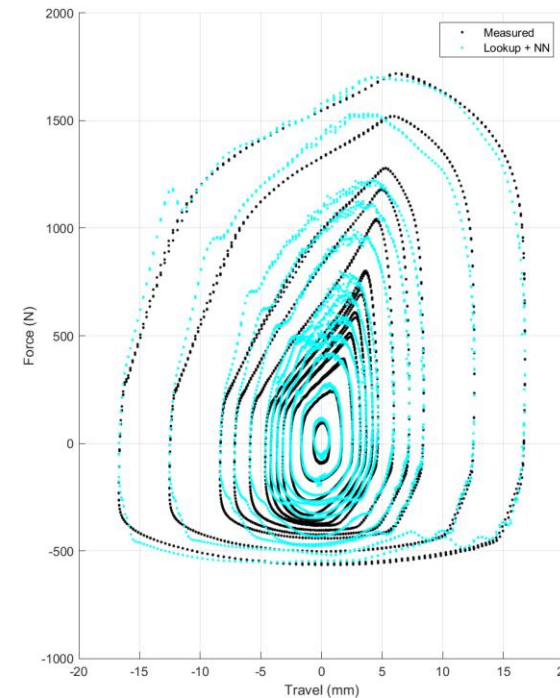
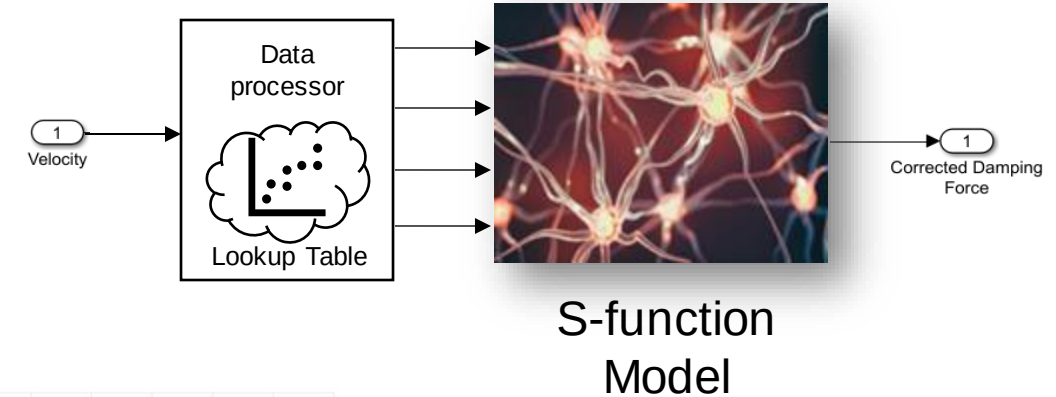


- SimScape models
- Based on PQ curves (exp. or CFD)

1D Physical model

3rd Generation : AI-MBD Hybrid models

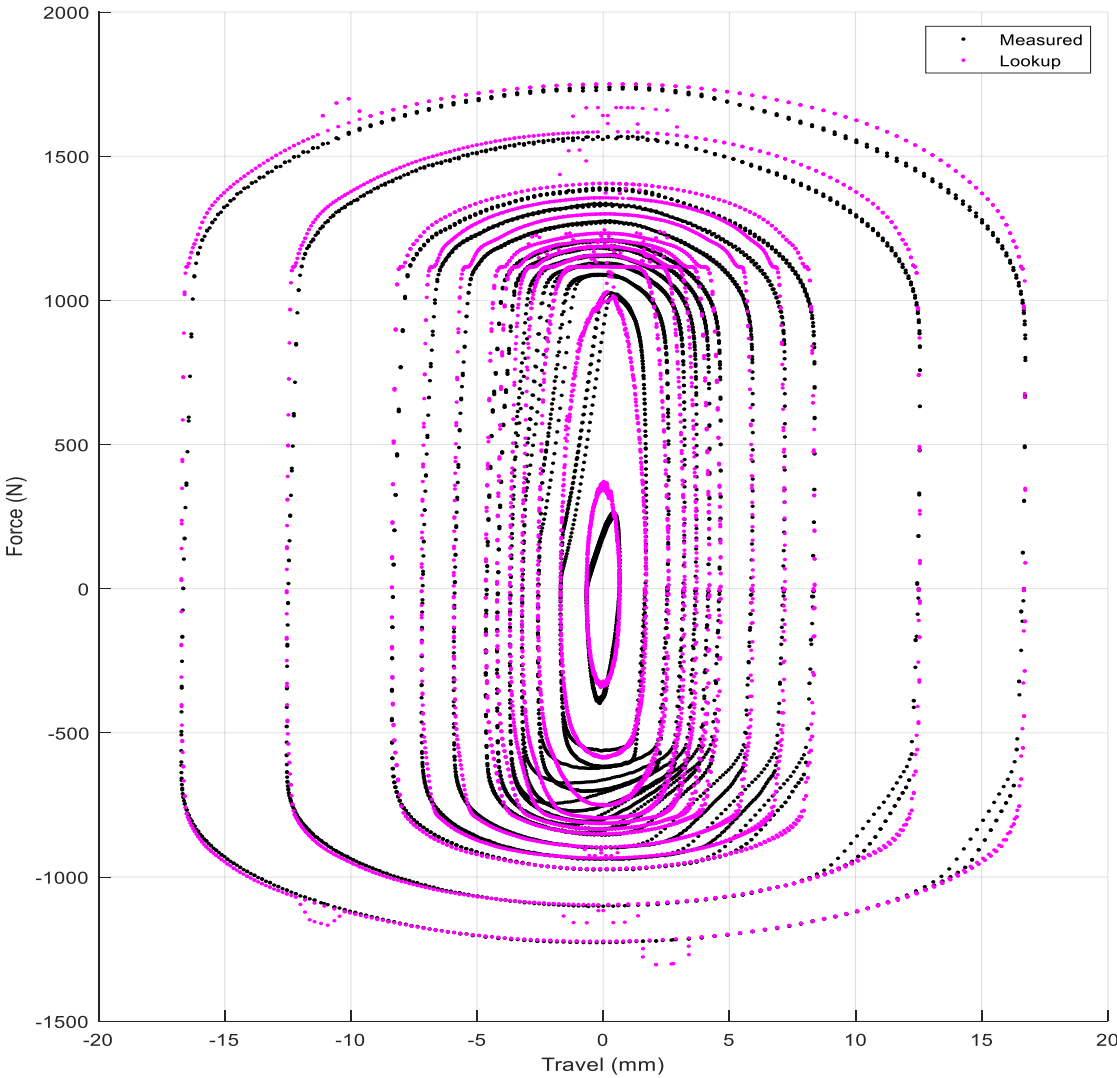
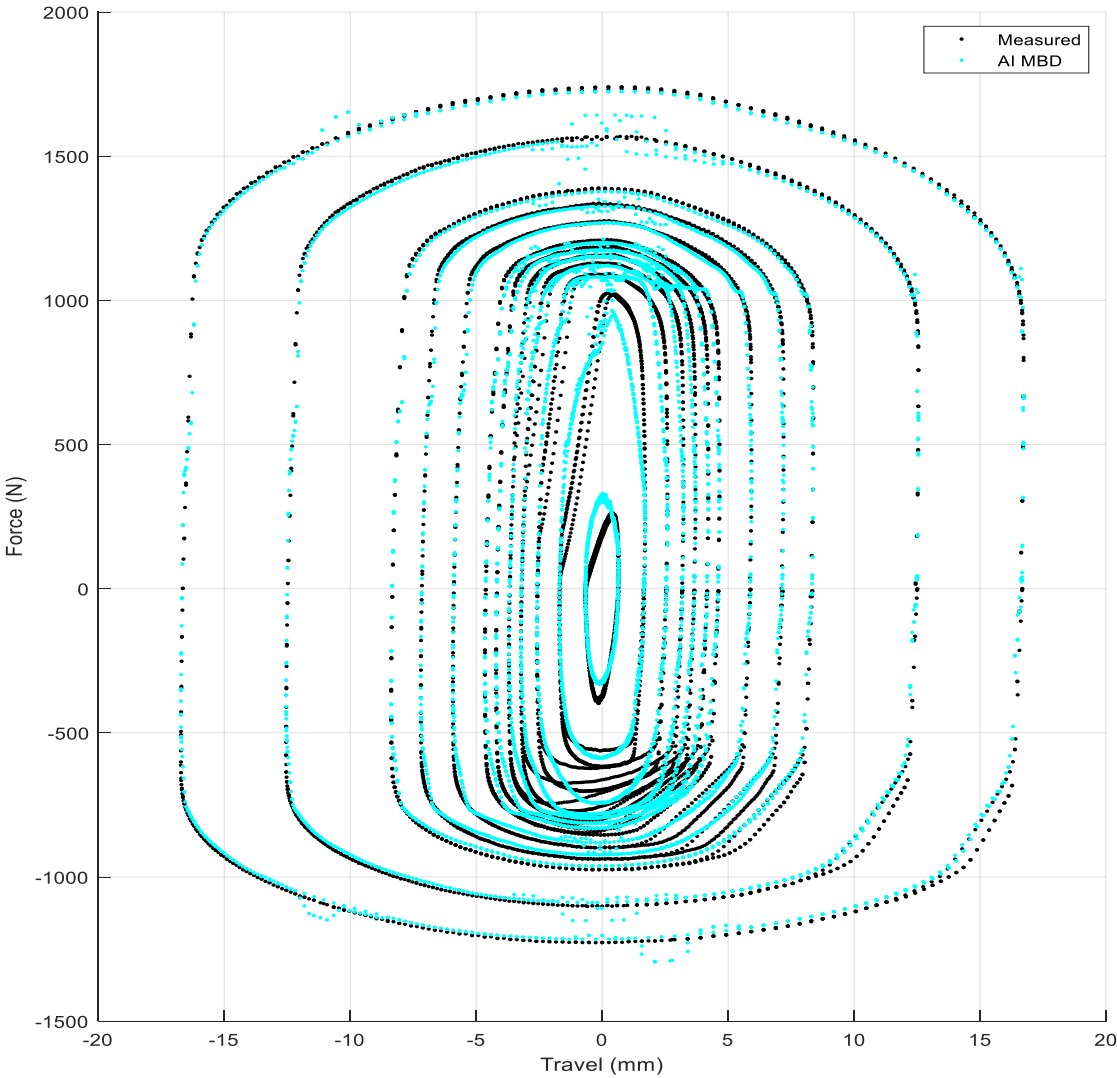
- The main idea consists of creating a basic **correction** model of an existing engineering base model
- Model pre-processor has a **lookup table** as an add-on feature
- Deep learning functions are now predicting force corrections to the basic engineering model while keeping it's **tunability** through the lookup tables
- Internal knowledge base is implemented into the S-function as well as the pre data processor



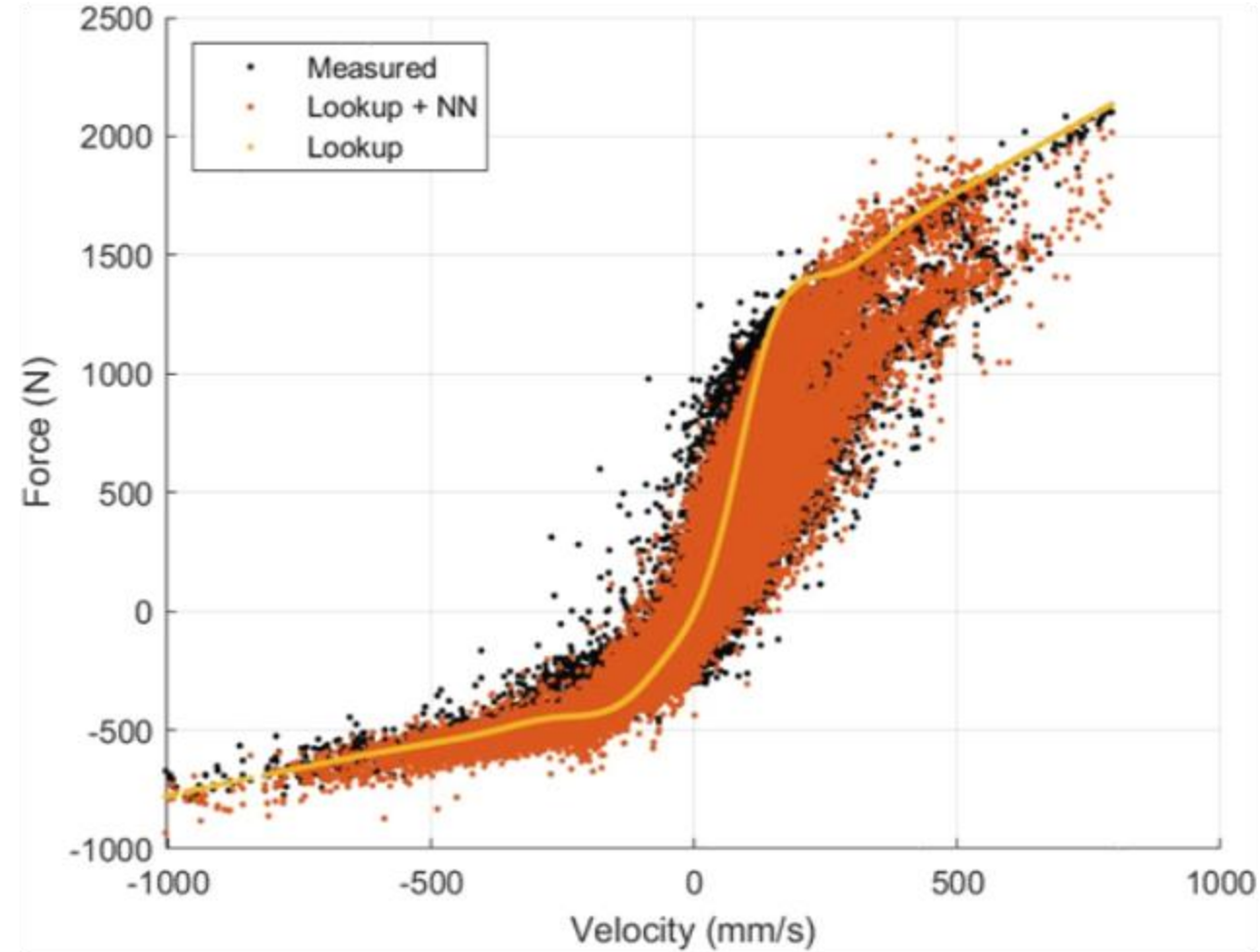
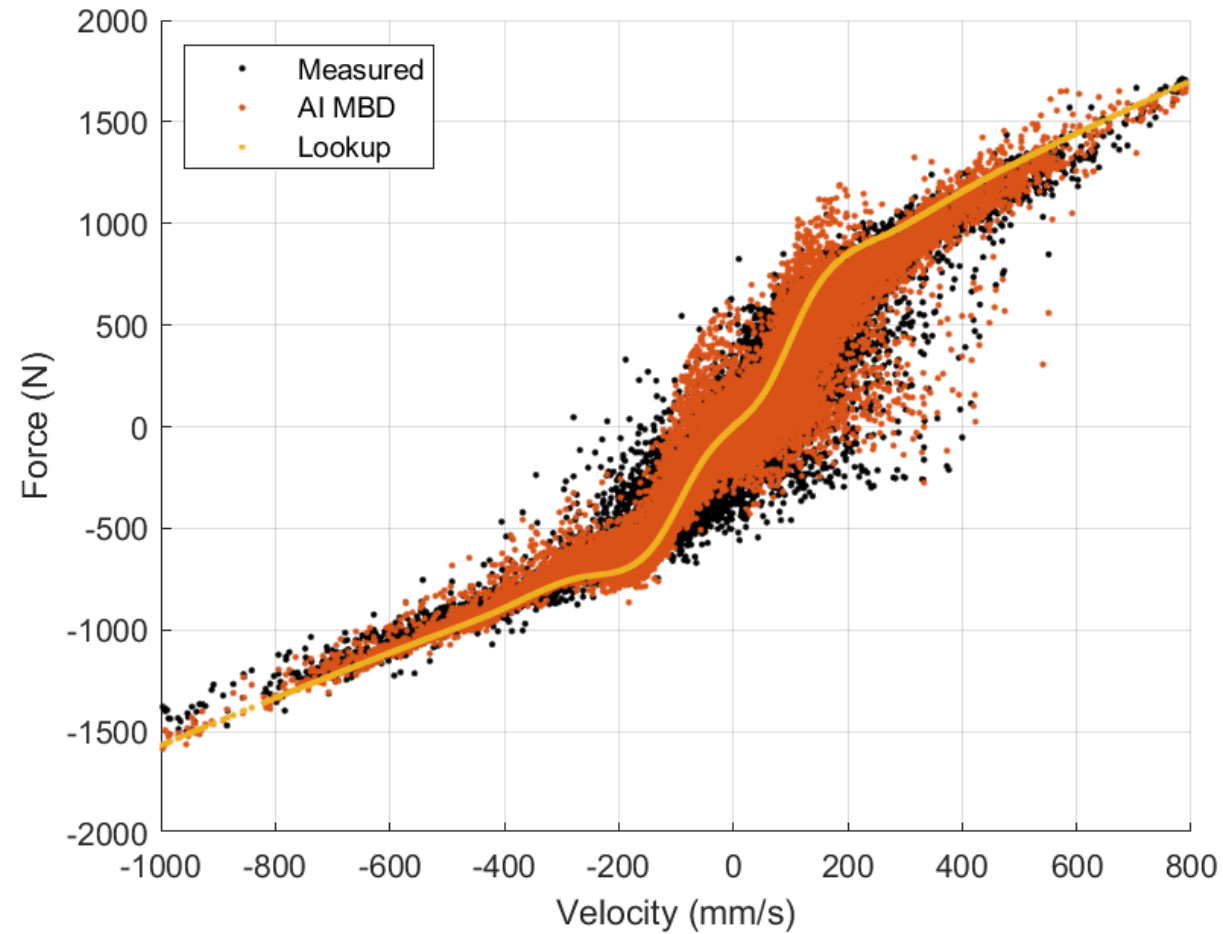


Bench Correlation Results

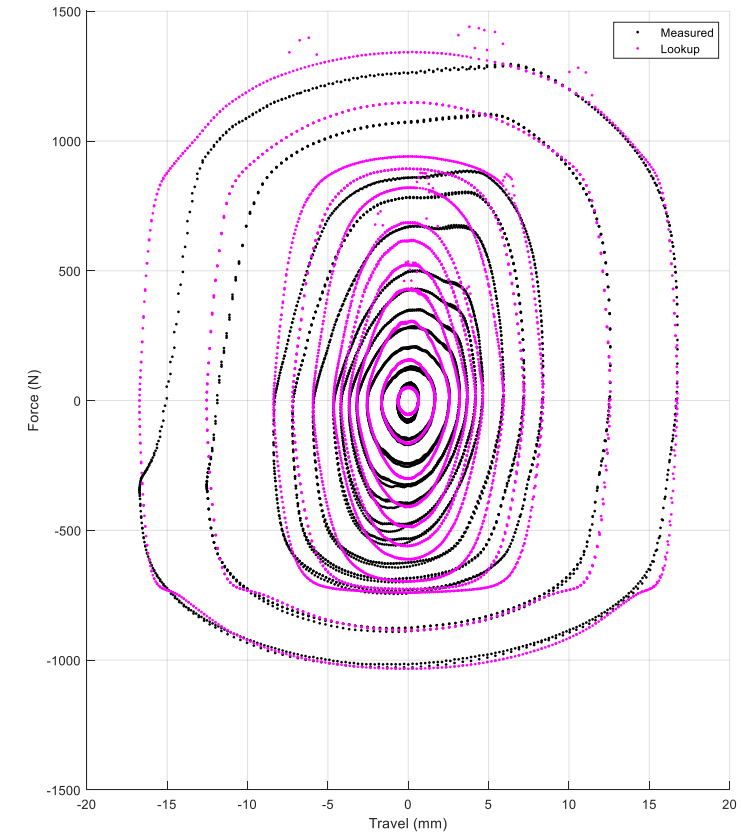
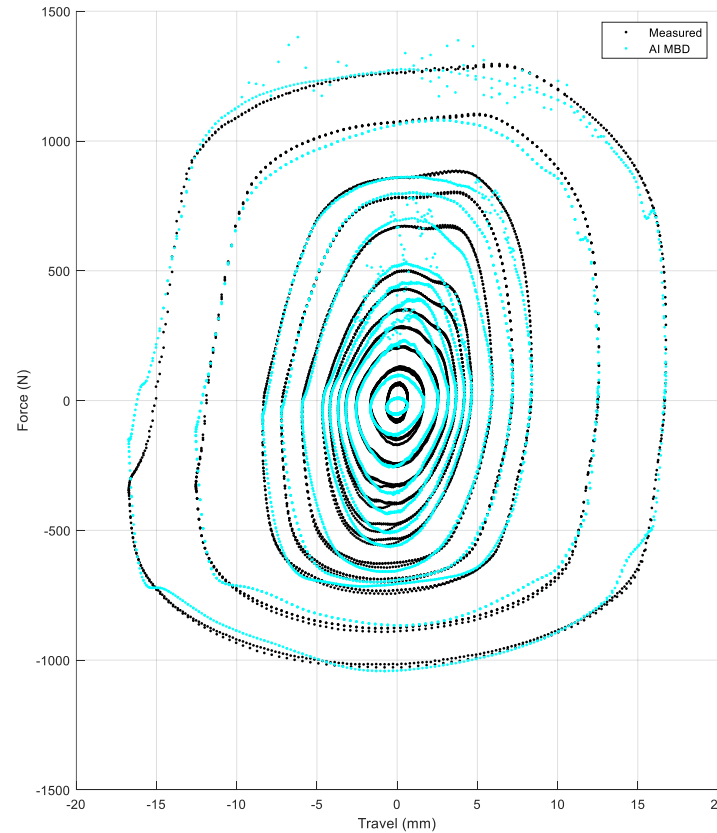
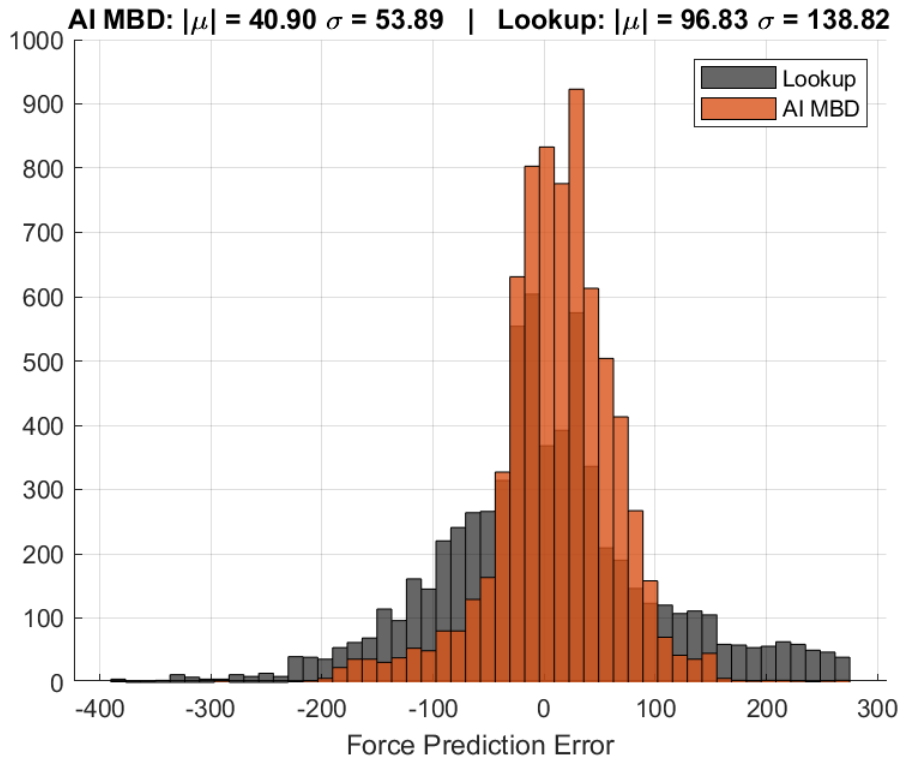
Application on Passive Dampers



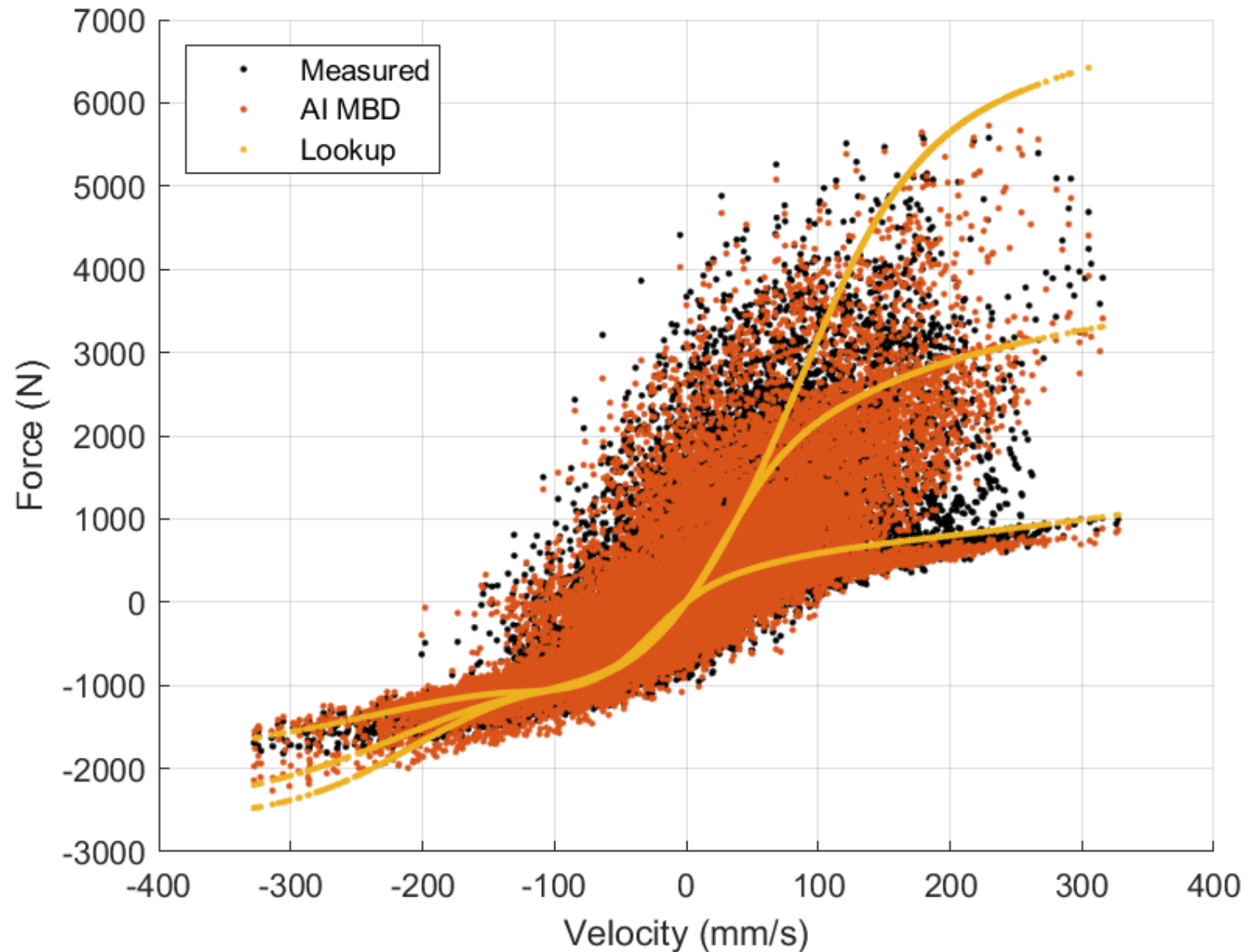
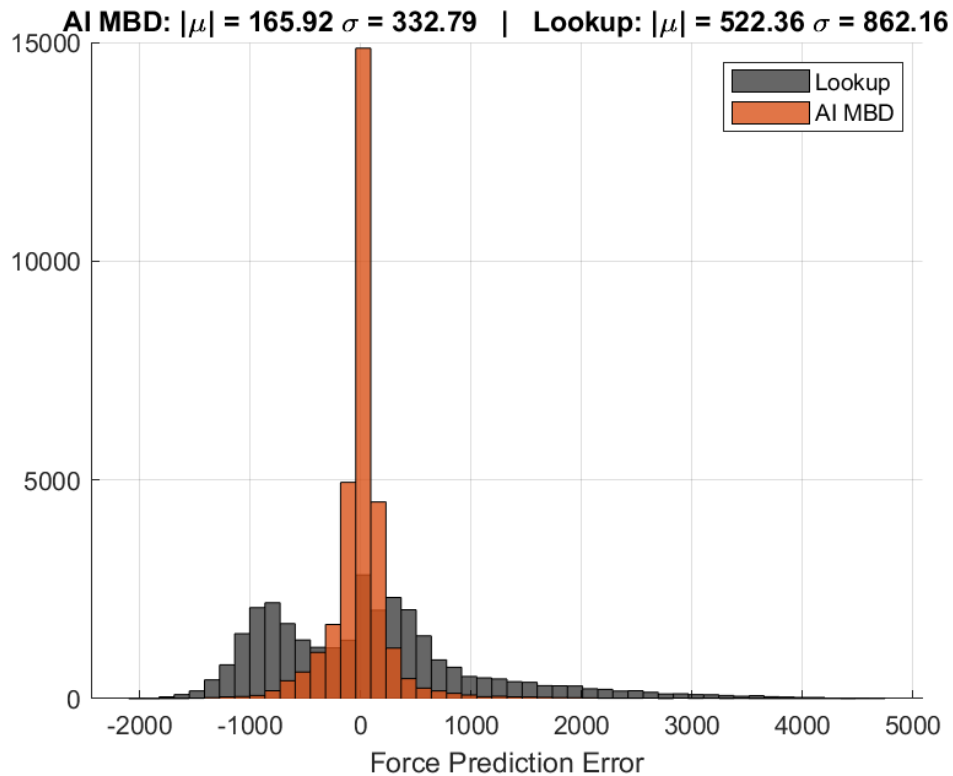
Application on FRD dampers



5Hz Sweep (data from a FRD damper)



Application to Semi-Active Dampers

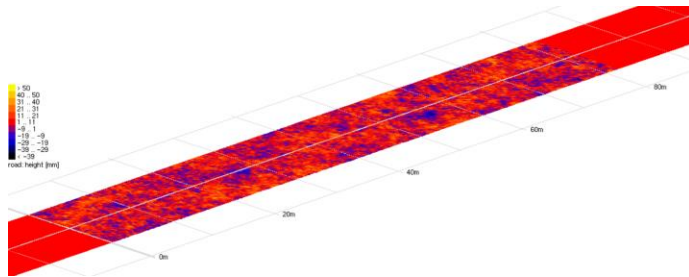




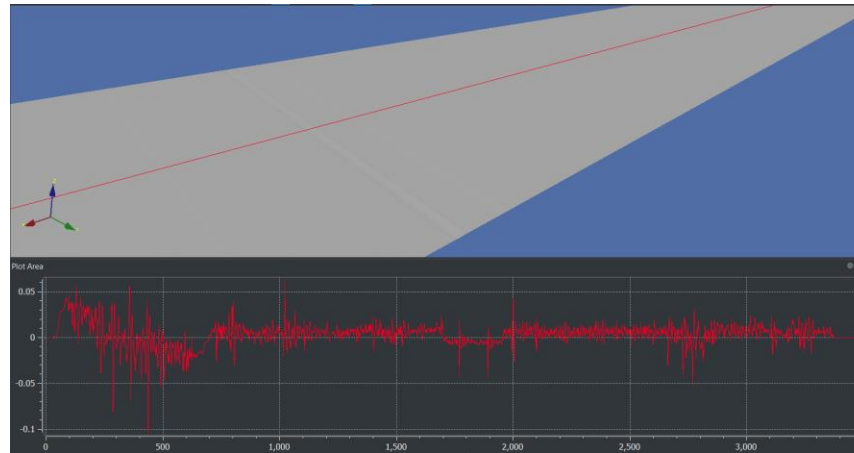
Full Vehicle Co-Sim Comparison

Full Vehicle Co-Sim Results

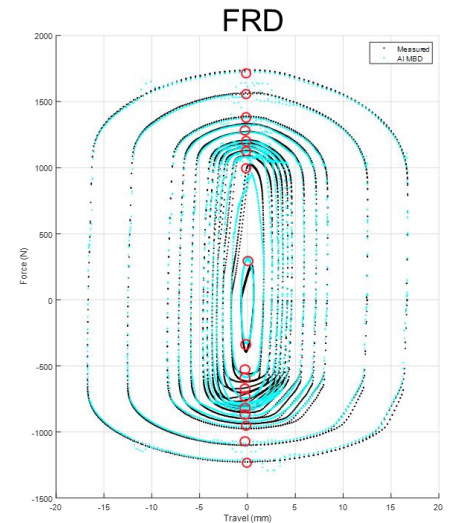
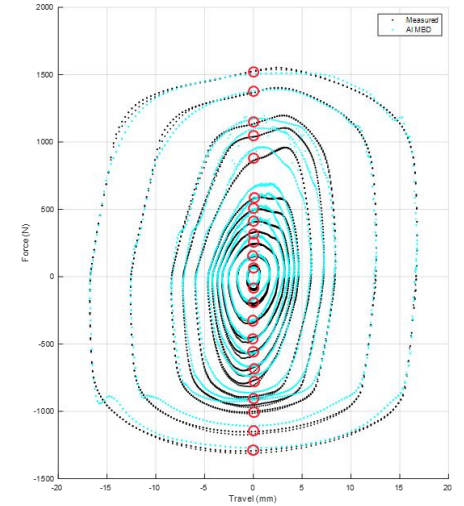
- Evaluate the differences in a **full vehicle** environment with different damper models
- Compare **AI-MBD** models with standard Lookup table modelling
- Steering On-center and rough roads:



Randomized surface

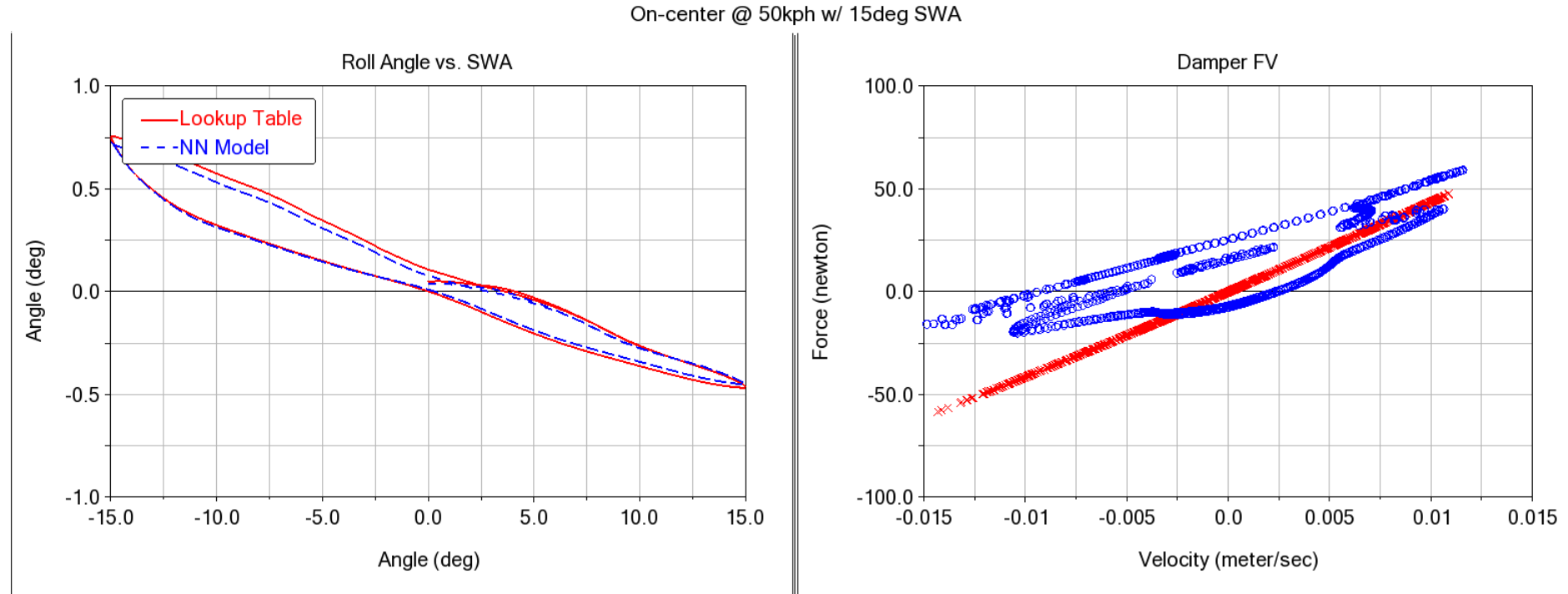


Mixed Rough Road



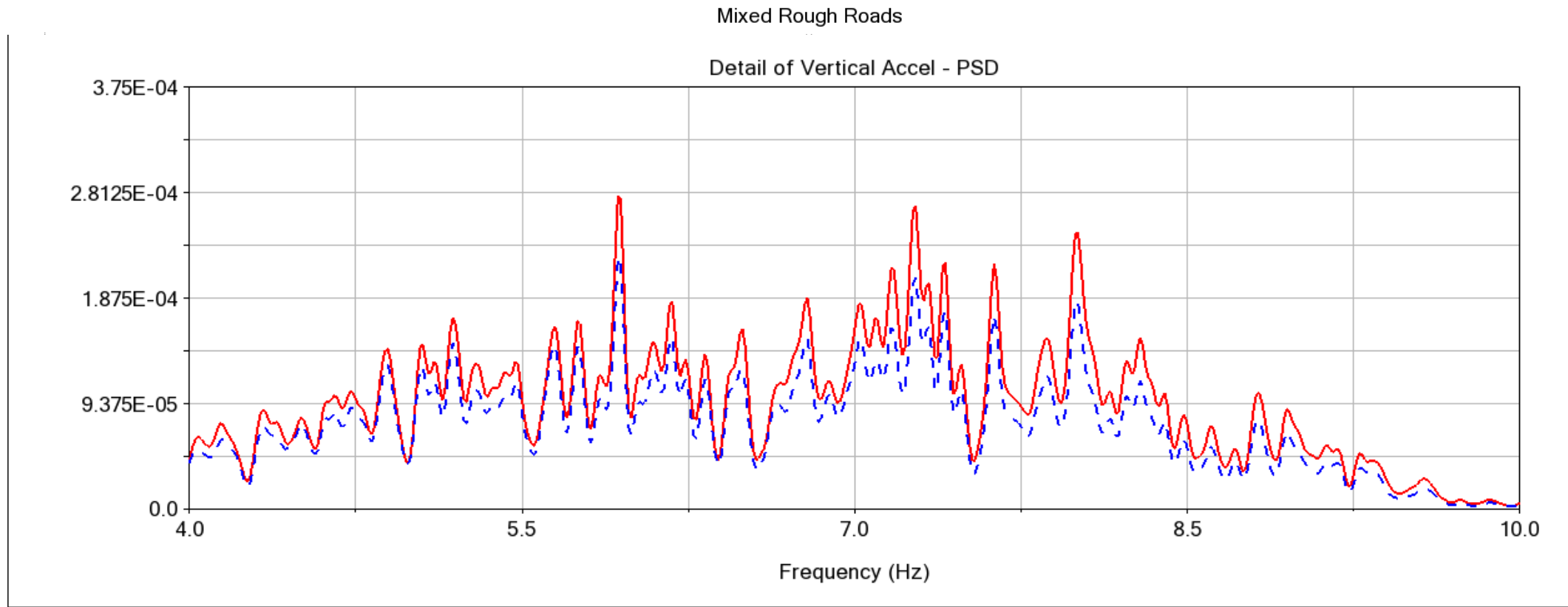
Passive

- Steering maneuver comparing for internal dampers – very low speed:



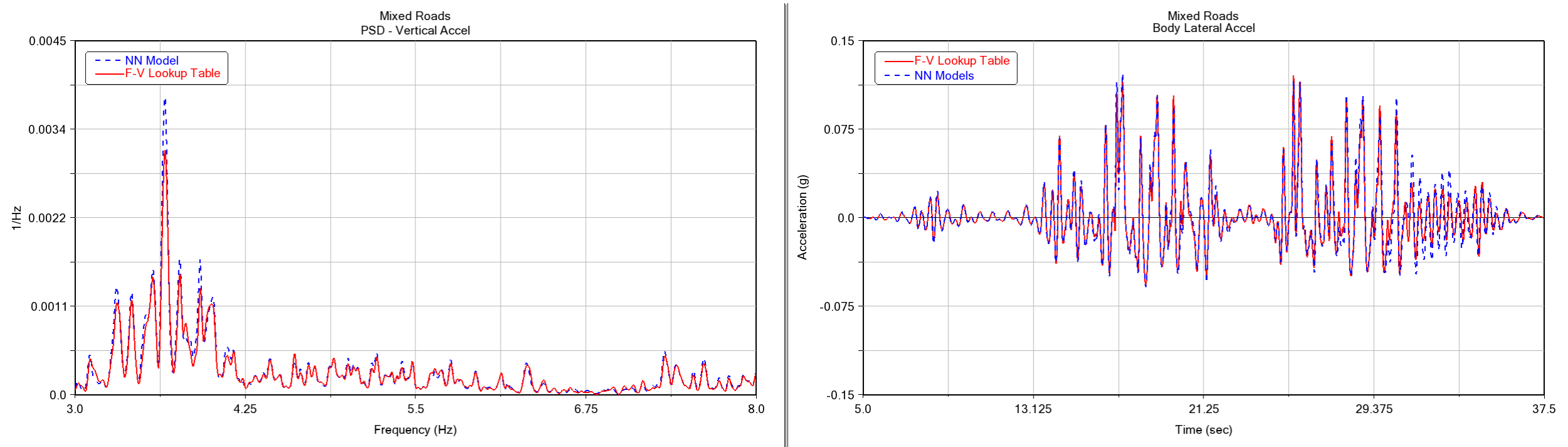
- The NN model characterization process can capture the **friction effects** helping on the results of low rod velocities.

- Ride examples using FRD damper:



- The usage of the NN models helps to capture effects on main ride metrics like **jerkiness** and vehicle **body control**.

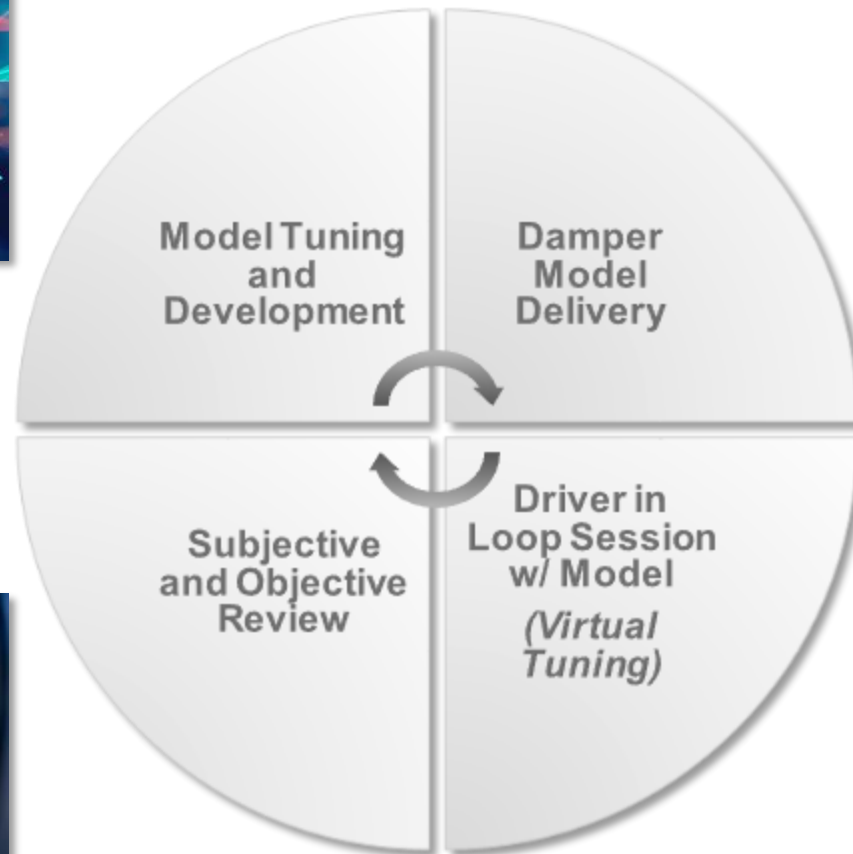
- Ride examples comparing passive damper models:



Wrapping up

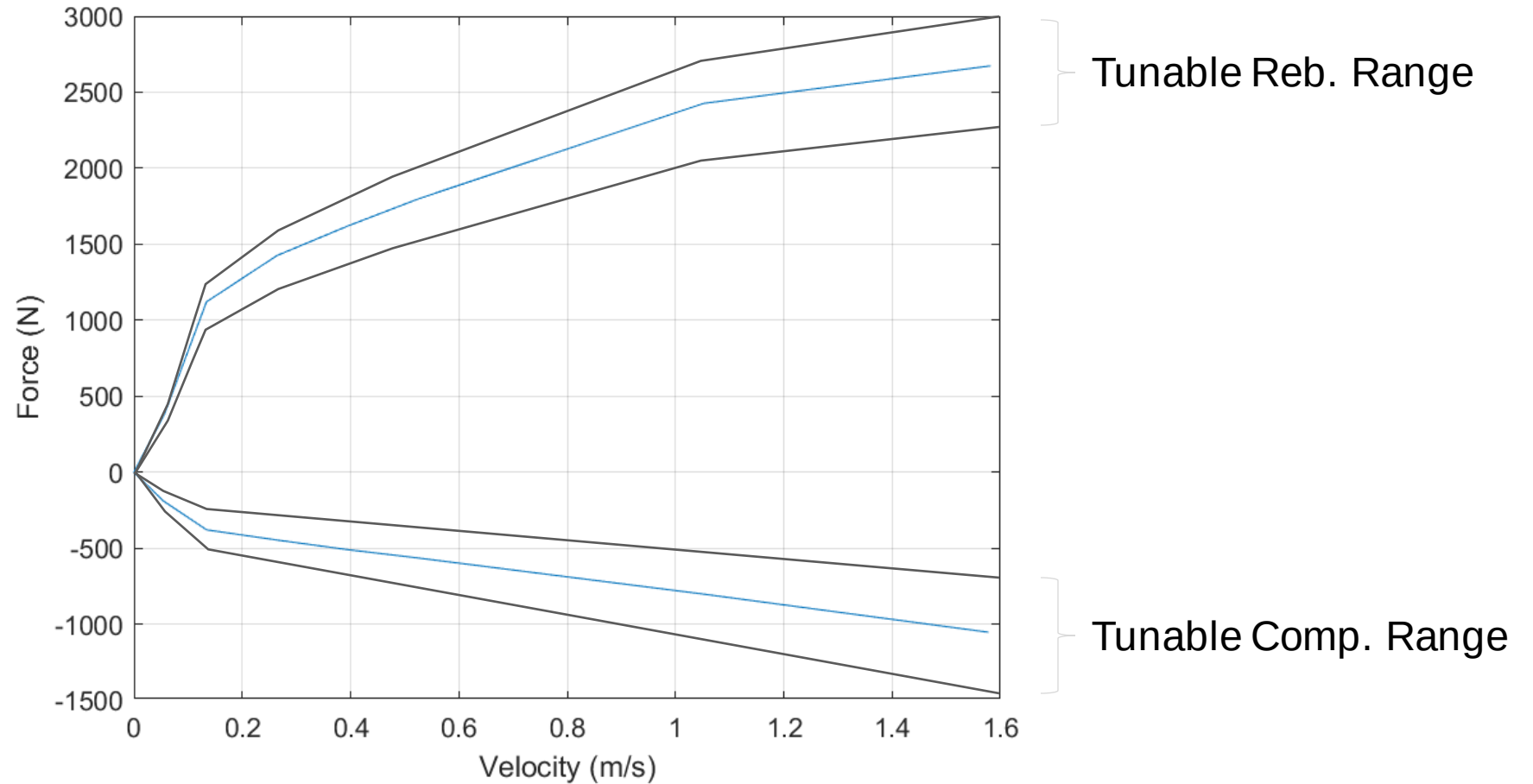
Driver In Loop Model Tuning and Development

Astemo aims to deliver the best performing damper models tailored for its customers needs. A large part of that is ensuring adhesion between models, subjective evaluation, and driver simulator experience.



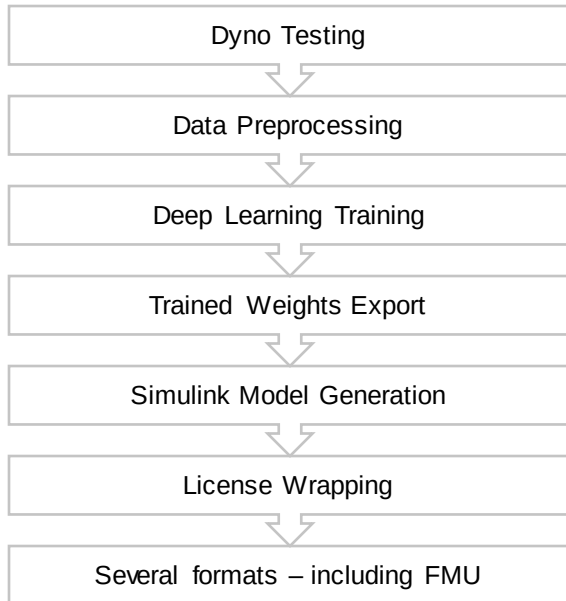
3rd Generation : AI-MBD Hybrid models

The tunable lookup table model would allow engineers to quickly run accurate full vehicle simulations with a simple change to the damper lookup table. The team is creating a library of different technologies to use as starting point.

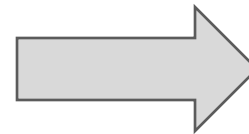
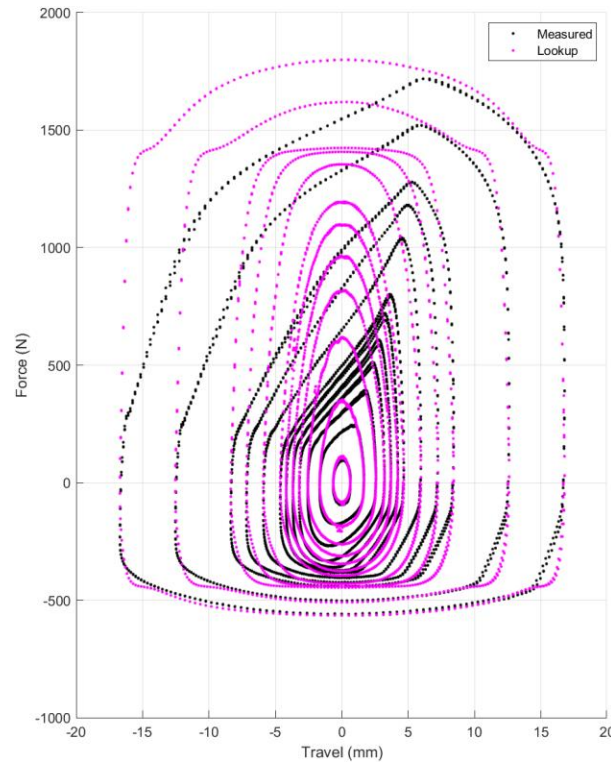


Benchmarking Competitor Dampers

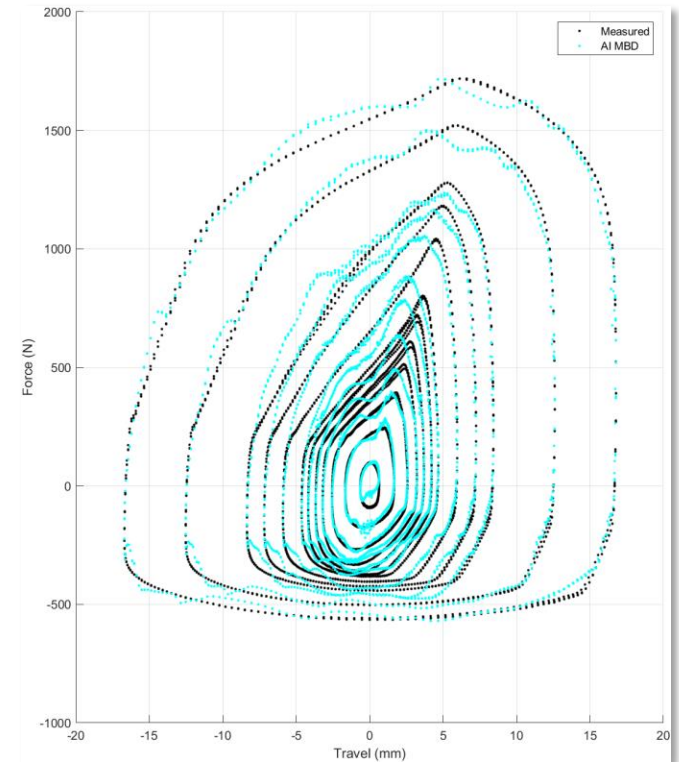
The generation of **AI-MBD** Deep Learning Models is not limited to only Hitachi Astemo designs. **Any damper model** could be generated allowing Hitachi Astemo to develop models of competitor dampers and evaluate performance.



7 Speed Spline Lookup



Deep Learning Model



Astemo