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HYUNDAI MOTOR GROUP
EUROPEAN TECHNICAL CENTER

APPLY & INNOVATE

Apply & Innovate 2020 – TECH WEEKS

Fitting ESP hydraulic parameters using CarMaker for Simulink and optimization algorithm

PUBLIC INTERNAL CONFIDENTIAL SECRET

Contents

Contents

Applus IDIADA: Who we are and what we do

Applus IDIADA is an engineering partner to the automotive industry providing complete solutions for product development projects worldwide.

International presence

Main Centres for Engineering, Testing and Homologation

Total: 2,530 people

HYUNDAI-KIA R&D

Global research and development infrastructure

- Korea: Namyang
- Asia: Hyderabad, Beijing and Yokohama
- USA: Michigan and California
- Europe: Rüsselsheim and Nürburg

Hyundai Motor Europe Technical Center

- Adaption of Hyundai, KIA and Genesis cars to European market demands
- Research & development for new technologies
- Located in Rüsselsheim since 2003
- 330+ employees and over 20 nations represented
- 7 departments + administration

Contents

Steering and ESC Performance Tuning at HiL-Bench

Objective of the Project:

- Fitting of Hydraulic Braking model by the use of Dynamic Measurements
- Integration of Brake-Test Box at Steering-HiL
- Validation of Vehicle Dynamics, Steering and Brake Behaviour at HiL-Bench
- Combined Performance Tuning of Steering and Brake Behaviour during Limit Handling

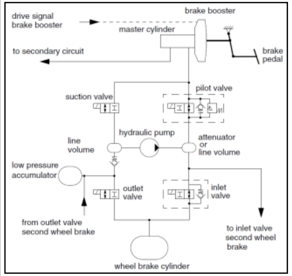
Real Hardware

Steering-HiL

Brake ECU (HiL)

Simulation

Hydraulic Braking Model



Vehicle Model

Steering and ESC Performance Tuning at HiL-Bench

Current Situation

- ESC tuning performed mainly in full vehicle on proving grounds

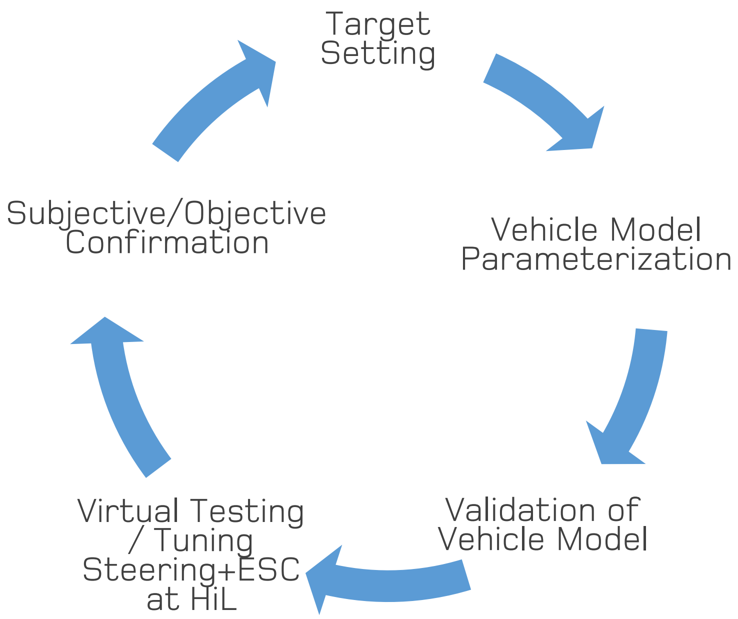
Motivation

- Shift from proving ground to laboratory and simulation
  » Safe time & resources
  » Virtual testing of wide range/physically not available vehicle variants
- Create efficient and robust tuning process

Outlook

- Application of methodology to support mass-production vehicle development

Virtual Approach with HiL

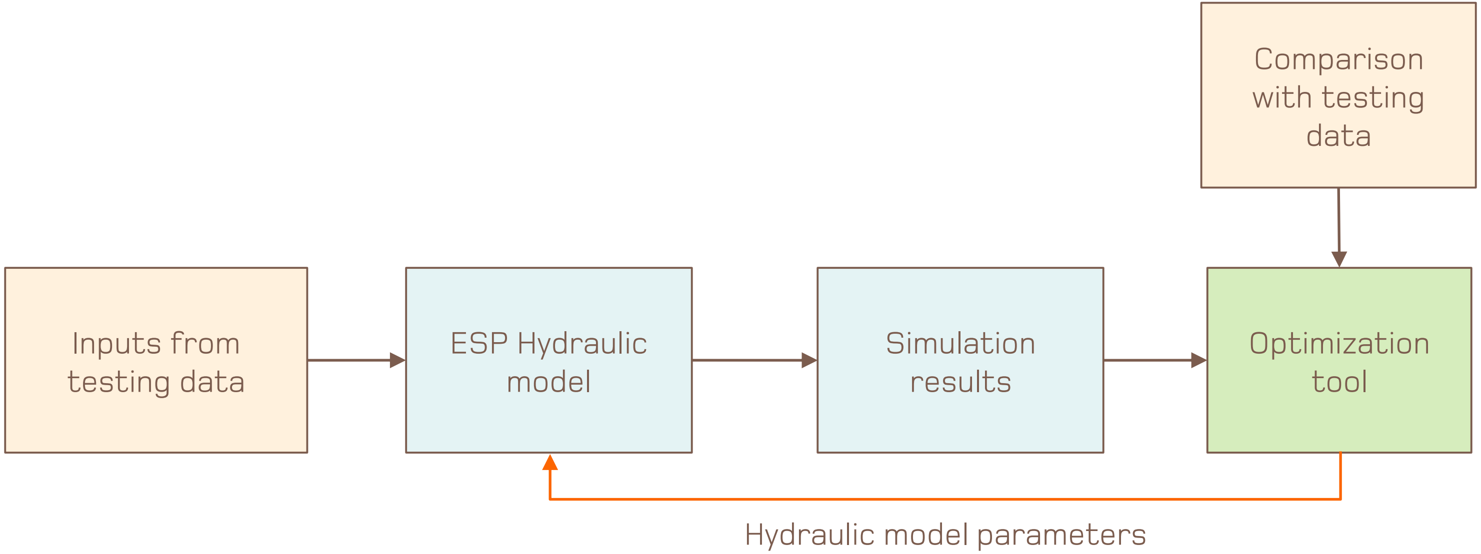


Contents

Project introduction

Main goal

To develop a methodology to identify ESP hydraulic model parameters based on measurement data from real testing and optimization techniques applied to simulation.



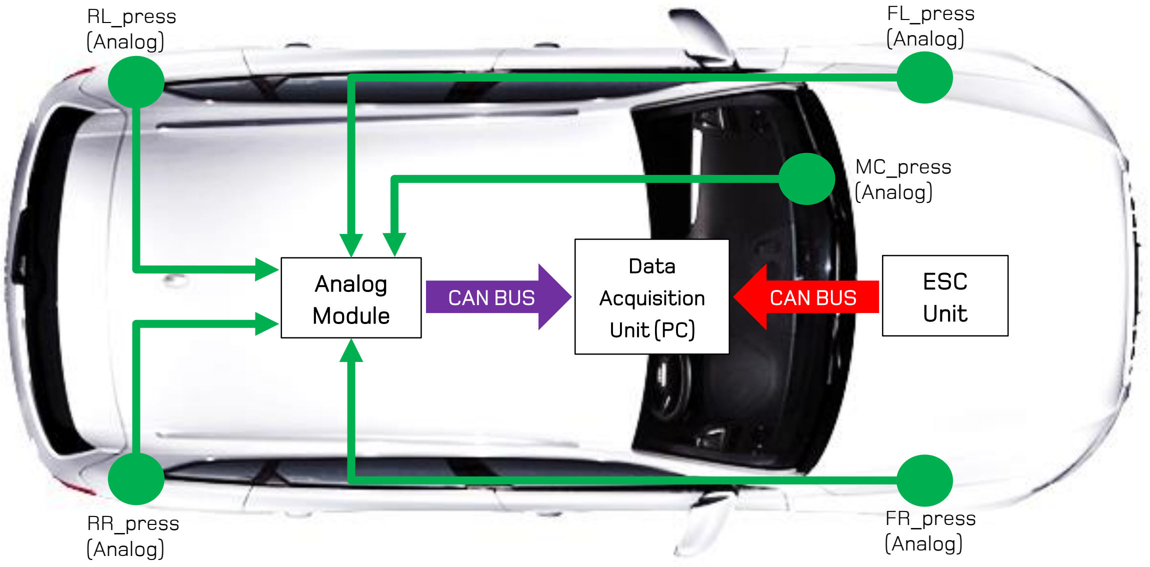
Contents

Testing on proving ground

- The goal of testing activities was to gather data to be used for the parameter identification procedure (to compare real testing data with simulation results).
- From the list of scenarios, a total of 8 cases were used for the optimization and 8 additional cases were used for validation.

ID	Scenario	Case
001	HighMu	10-20bar 100kph
002		40-50bar 100kph
003		panic ~150bar
004		progressive ~150bar
005	Lane change	VDA
006	LowMu basalt	10-20 bar
007		panic ~150 bar
008		progressive ~150 bar
009	LowMu ceramic	10-20 bar
010		panic ~150bar
011		progressive ~150bar
012	SplitMu Ceramic LowLeft	10-20bar 50kph
013		10-20bars 80kph
014		panic ~150bar 50kph
015		panic ~150bar 80kph
016		progressive ~150bar 50kph
017		progressive ~150bar 80kph
018	SplitMu Ceramic LowRight	10-20bar 50kph
019		10-20bars 80kph
020		panic ~150bar 50kph
021		panic ~150bar 80kph
022		progressive ~150bar 50kph
023		progressive ~150bar 80kph
024	TransMu H2L	10-20bar 60kph
025		panic 150bar 60kph
026		progressive 150bar 60kph
027	TransMu L2H	10-20bar 60kph
028		panic 150bar 60kph
029		progressive 150bar 60kph
SUM	8 scenarios	29 cases

Testing on proving ground



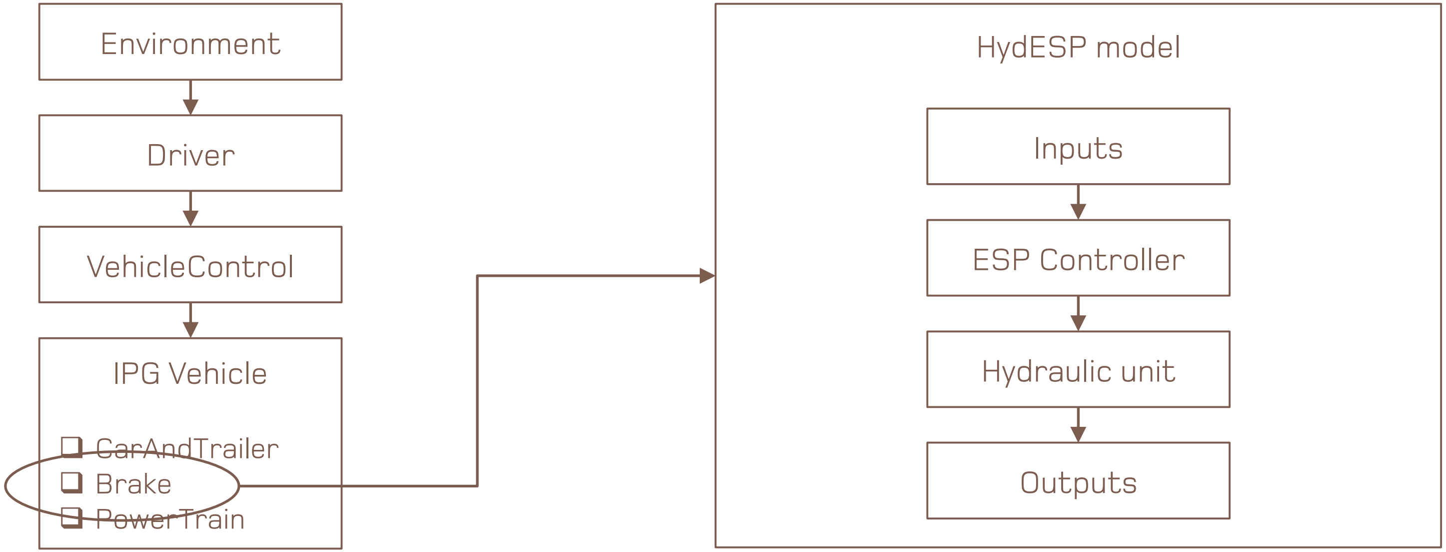
- The vehicle was equipped with analog pressure sensors at the four wheels and at the master cylinder.
- A specific ESC unit was fitted to log internal signals that were not available on vehicle CAN interface. The support of ESC supplier was needed for this process and for the configuration of the acquisition software.
- All the signals were logged through a single data acquisition unit.

Contents

Fitting ESP hydraulic parameters

Starting point

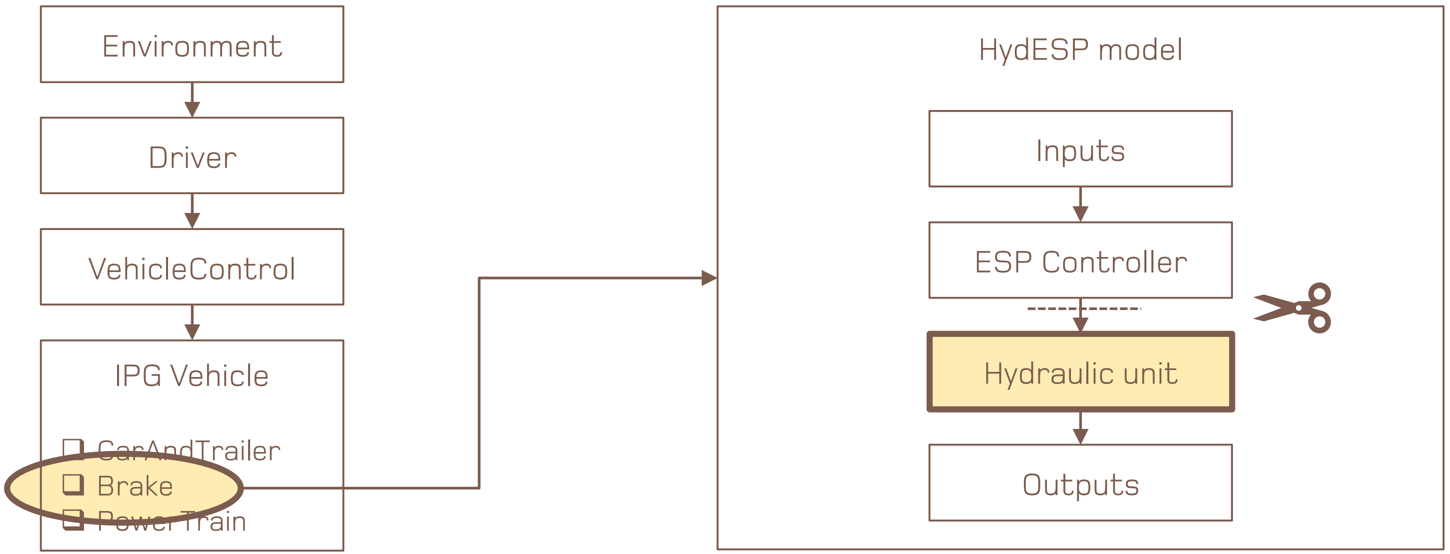
- IPG CarMaker provides a hydraulic brake system (HydESP) included in CarMaker for Simulink libraries. This model can be used in full vehicle simulations.
- The following diagram describes the simplified structure of CarMaker for Simulink-HydESP model:



Fitting ESP hydraulic parameters

HydESP model preparation

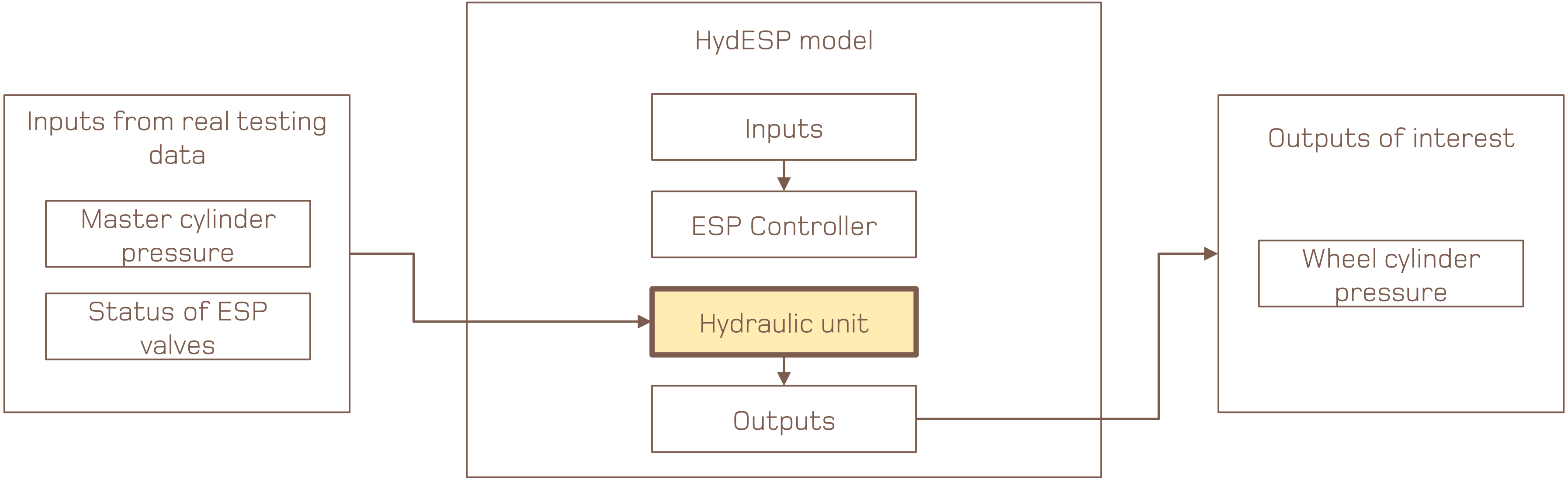
- Only focused on the Hydraulic unit model ("ESP System"). Overall vehicle dynamic simulation outputs (such as lateral acceleration) were not relevant to review on this stage.



Fitting ESP hydraulic parameters

HydESP model preparation

- The required inputs for the Hydraulic unit model were provided directly from testing data.
- Only wheel cylinder pressure output values were required to evaluate the system.



Fitting ESP hydraulic parameters

Optimization workflow

Fitting ESP hydraulic parameters

Optimization workflow

HEEDS ⟷ MATLAB ⟷ IPG AUTOMOTIVE

- Global optimization software
- SHERPA algorithm
- Compatibility with MATLAB

- Load the different scenarios
- Generation of new ESP parameters file
- Calculation of the metrics

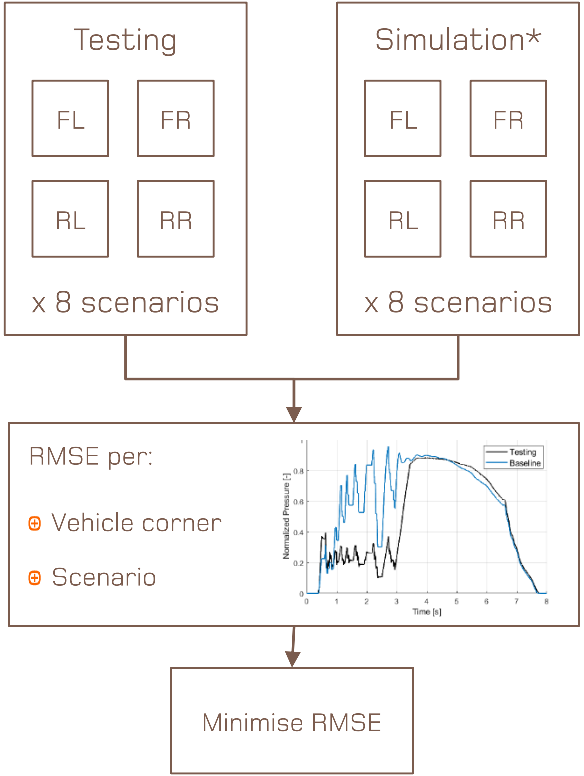
- Provide the Hydraulic unit model
- Launched by MATLAB using CarMaker for Simulink

Fitting ESP hydraulic parameters

Optimization workflow - Metrics

- Wheel cylinder pressure values of the whole simulation event (for each vehicle corner) are obtained for each scenario and for every single iteration.
- Root Mean Square Error (RMSE) between testing and simulation results is the main metric for the performance function of the optimization.

$$RMSE = \sqrt{\sum_{i=1}^{n} \frac{(y_{testing_i} - y_{simulation_i})^2}{n}}$$



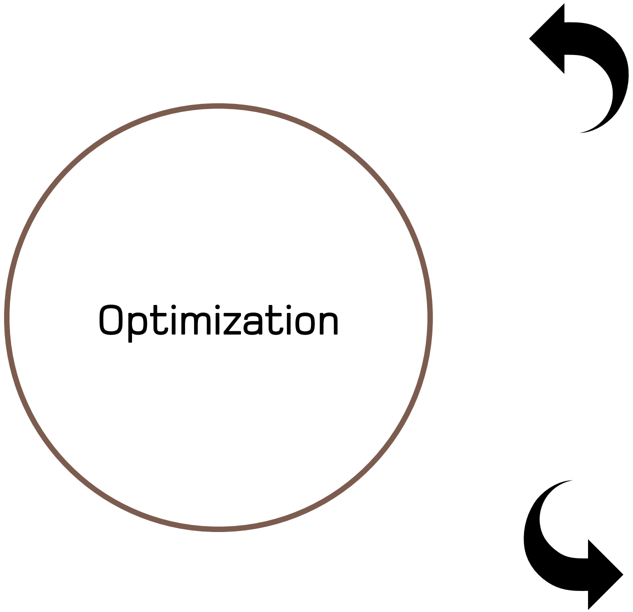
* Per iteration

Fitting ESP hydraulic parameters

Optimization workflow

GOALS

- Achieve a good overall behaviour for all the scenarios evaluated.
- Obtain a RMSE lower than 10 (bar) for all the scenarios.



INPUT (VARIABLES)

46 parameters from the Hydraulic unit were set as variables.

OUTPUT (RESPONSES)

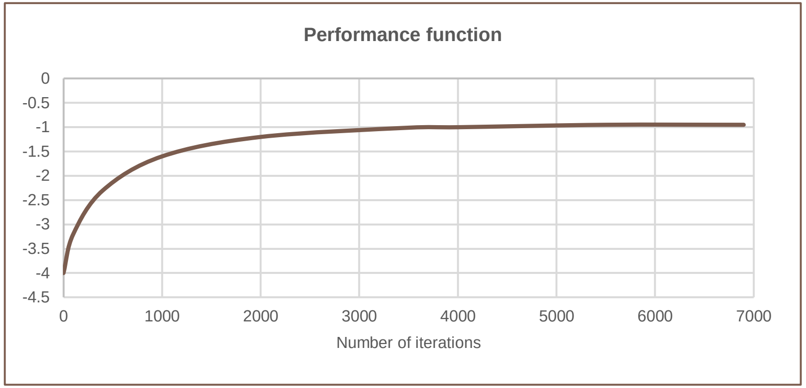
A total of 32 responses (4 wheel cylinder pressure per 8 scenarios) per iteration.

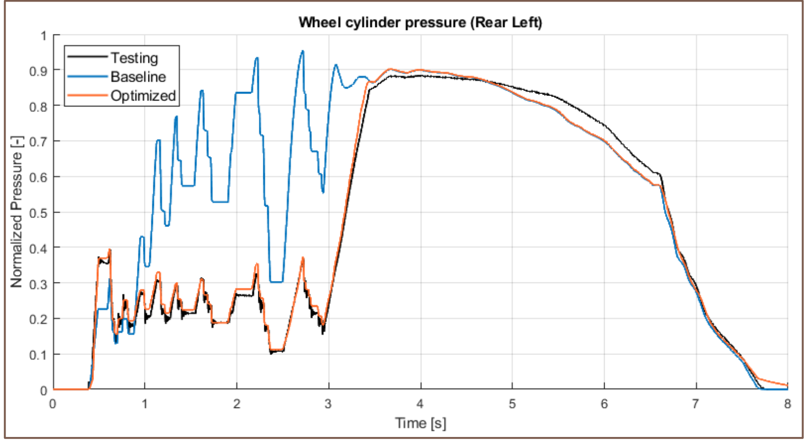
Fitting ESP hydraulic parameters

Results

- A total of 6900 iterations were evaluated to achieve the final set of ESP parameters.
- Performance function of the optimization shows an asymptotic behaviour after 3500 iterations.

- A visual comparison between testing and simulation results was required to ensure that the metrics and the optimization process were set correctly.
- As an example, the right image corresponds to High Mu panic scenario (Rear left wheel cylinder pressure).

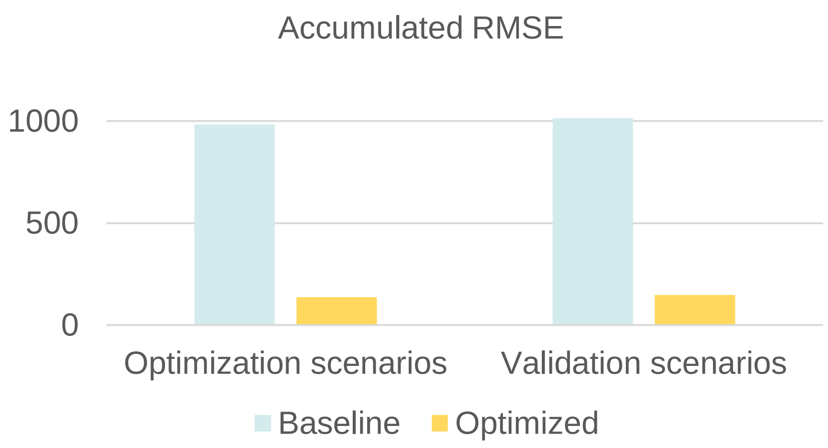


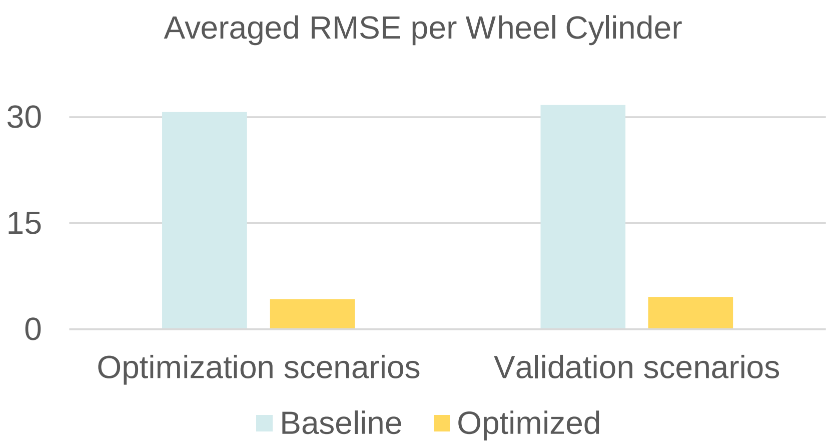


Fitting ESP hydraulic parameters

Validation

- To ensure that the optimized set of ESP parameters can be used for the overall range of scenarios, an additional set of 8 cases were evaluated as well.
- The following diagram sums up the results of the optimization and the validation stages:





Contents

Conclusions and future work

- A methodology to identify ESP hydraulic model parameters based on measurement data from real testing and optimization techniques has been developed, tested and validated.
- The results obtained from the optimization and validation scenarios are within the specified targets. Consequently, the set of optimized ESP parameters provides an acceptable range of correlation in a wide spectrum of scenarios.
- Therefore, the set of optimized ESP parameters can be tested in a HiL test bench as a future activity.
- It could be interesting to compare CarMaker HydESP model with a highly-detailed ESP virtual model, to evaluate differences in terms of simulation time and performance of the results.

Thank you very much for your attention

Q&A

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