ASCENT

Examples of Projects

4th Training in Rio de Janeiro, BRA

6th-9th of May 2019

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Content

1. Industrial Projects
2. R&D related Projects
3. Educational based Projects

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1. Industrial Projects

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Friction Investigations

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Friction Investigations

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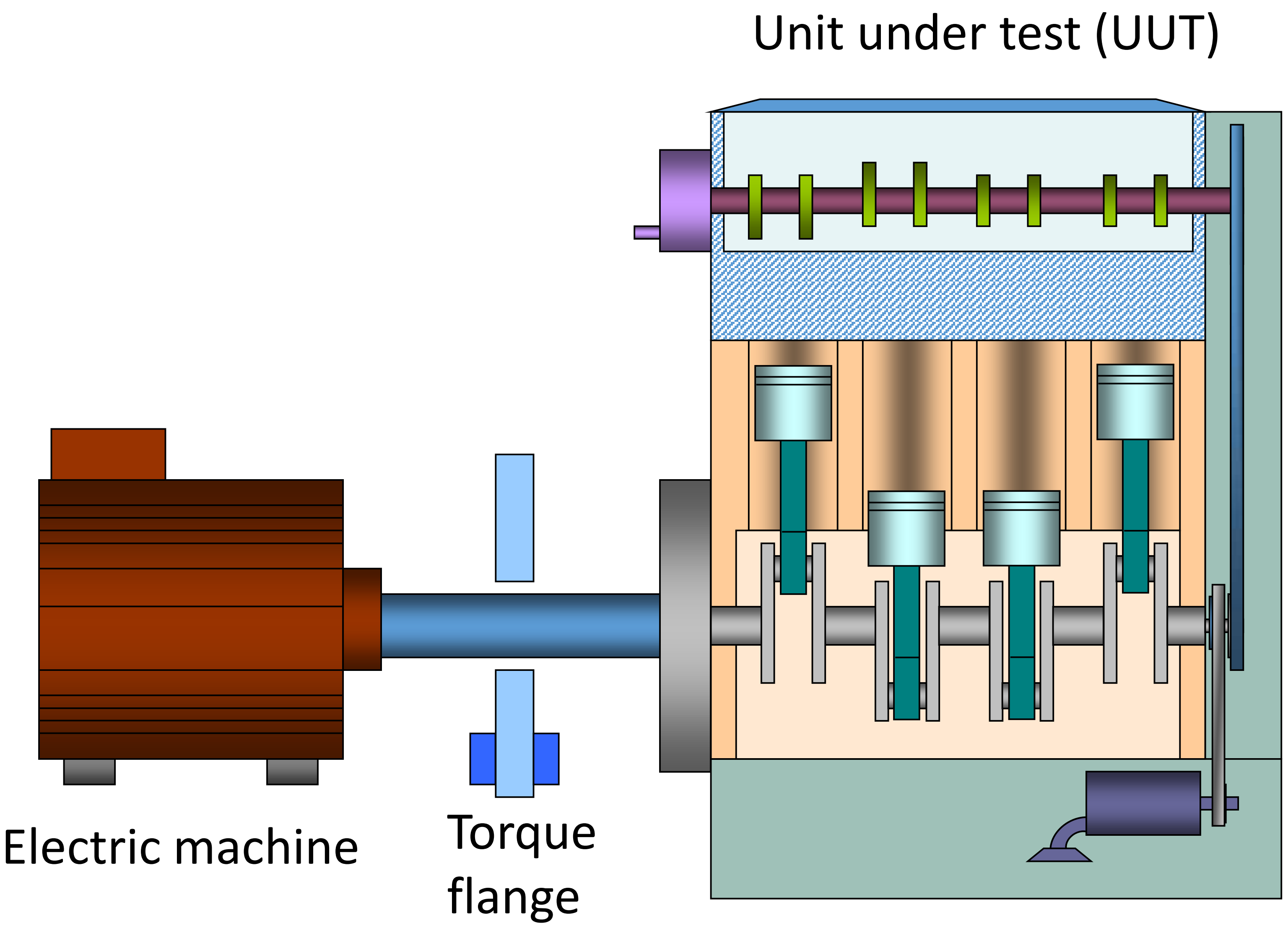
Friction Investigations



Strip-down method

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Friction Investigations

1.Test matrix

Engine: xyz

Filename \ Part	Crankshaft	Pistons & conrods	Oil pump	Cylinder head / valvetrain	Vacuum pump	Alternator	Power steering pump	A/C pulley	Idler pulley and tensioner	Oil level (l)	Oil temp (°C)	Valve lift (mm)
-000001	●	●	●	●	●					4	~ 90°	9,6
-000002	●	●	●	●	●					3	35	9,6
-000003	●	●	●	●	●					3	90	9,6
-000004	●	●	●	●	●					4	90	9,6
-000005	●	●	●	●	●					2	90	9,6
-000006	●	●	●	●	●					1	90	9,6
-000007	●	●	●	●	●					3	120	9,6
-000008	●	●	●	●	●					3	140	9,6
-000009	●	●	○		○					1	90	
-000010	●	●	○		○					2	90	
-000011	●	●	○		○					3	90	
-000012	●	●	○		○					4	90	
-000013	●	●			○					1	35	
-000014	●	●			○					1	90	
-000015	●	●			○					1	120	
-000016	●	●			○					1	140	
-000017	●	●			○					2	90	
-000018	●	●			○					3	90	
-000019	●	●			○					4	90	
-000020	●				○					1	35	
-000021	●				○					1	90	
-000022	●				○					1	120	
-000023	●				○					1	140	
-000025	●		●	·	●					1	35	
-000026	●		●	·	●					1	90	
-000027	●		●	·	●					1	120	
-000028	●		●	·	●					1	140	
-000029	●		●	·	○					1	35	
-000030	●		●	·	○					1	90	
-000031	●		●	·	○					1	120	
-000032	●		●	·	○					1	140	
-000033	●			●						1	35	9,6
-000034	●			●						1	35	5
-000035	●			●						1	35	0,8
-000036	●			●						1	35	0,3
-000037	●			●						1	90	0,3
-000038	●			●						1	90	0,8
-000039	●			●						1	90	5
-000040	●			●						1	90	9,6

Results

- array of tests
- torque of friction
- contribution of consumers

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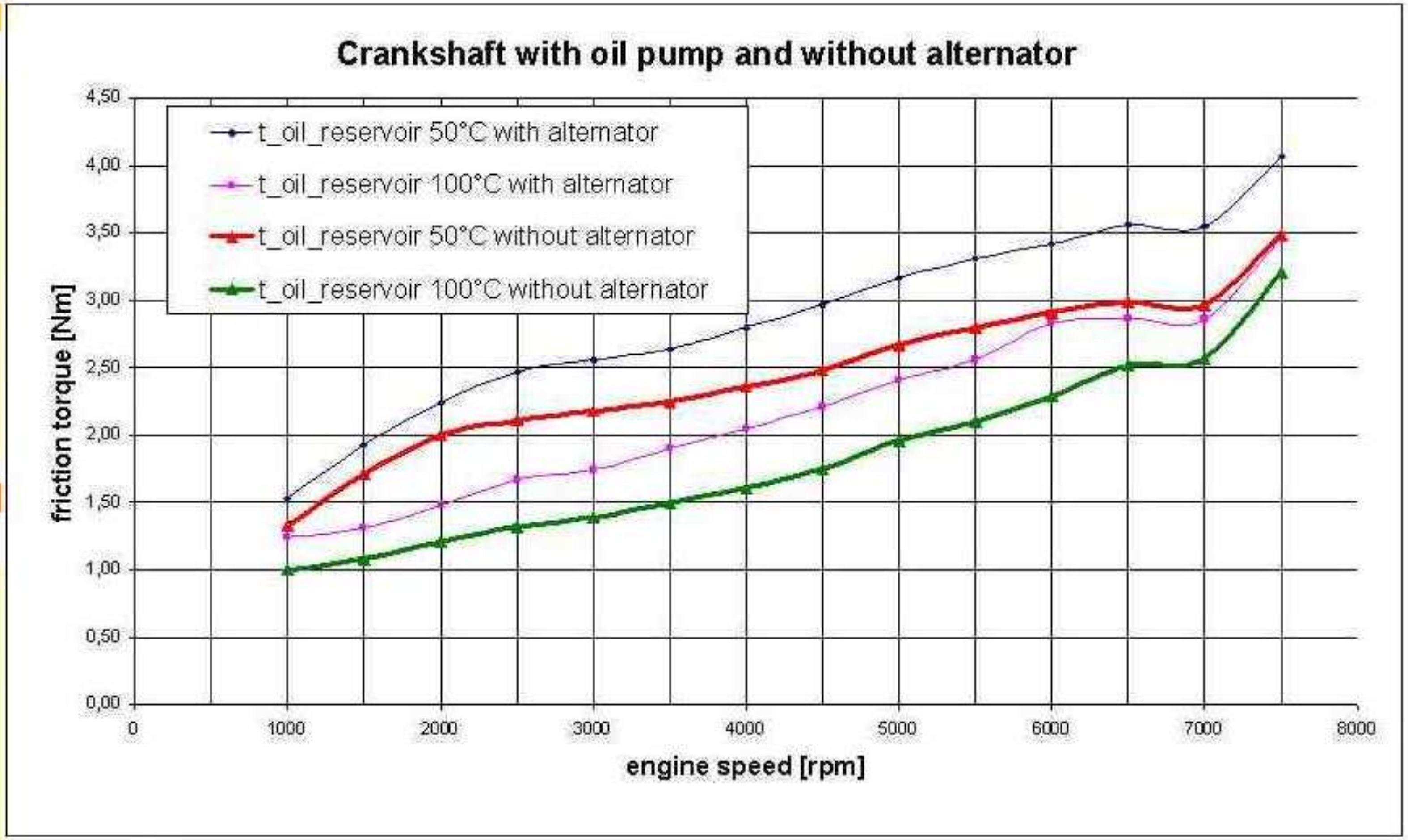
Friction Investigations

t_oil_reservoir 50°C		
n	Md	Md
1000	1,53	1,33
1500	1,93	1,71
2000	2,24	2,00
2500	2,47	2,11
3000	2,56	2,18
3500	2,64	2,25
4000	2,80	2,36
4500	2,97	2,48
5000	3,17	2,67
5500	3,31	2,80
6000	3,42	2,91
6500	3,56	2,99
7000	3,55	2,97
7500	4,07	3,49

t_oil_reservoir 100°C		
n	Md	Md
1000	1,24	1
1500	1,31	1,08
2000	1,48	1,21
2500	1,67	1,32
3000	1,74	1,39
3500	1,9	1,5
4000	2,05	1,61
4500	2,21	1,75
5000	2,41	1,96
5500	2,56	2,1
6000	2,83	2,29
6500	2,87	2,52
7000	2,86	2,57
7500	3,47	3,21



Md Crankshaft with oil pump and alternator
Md Crankshaft with oil pump and without alternator

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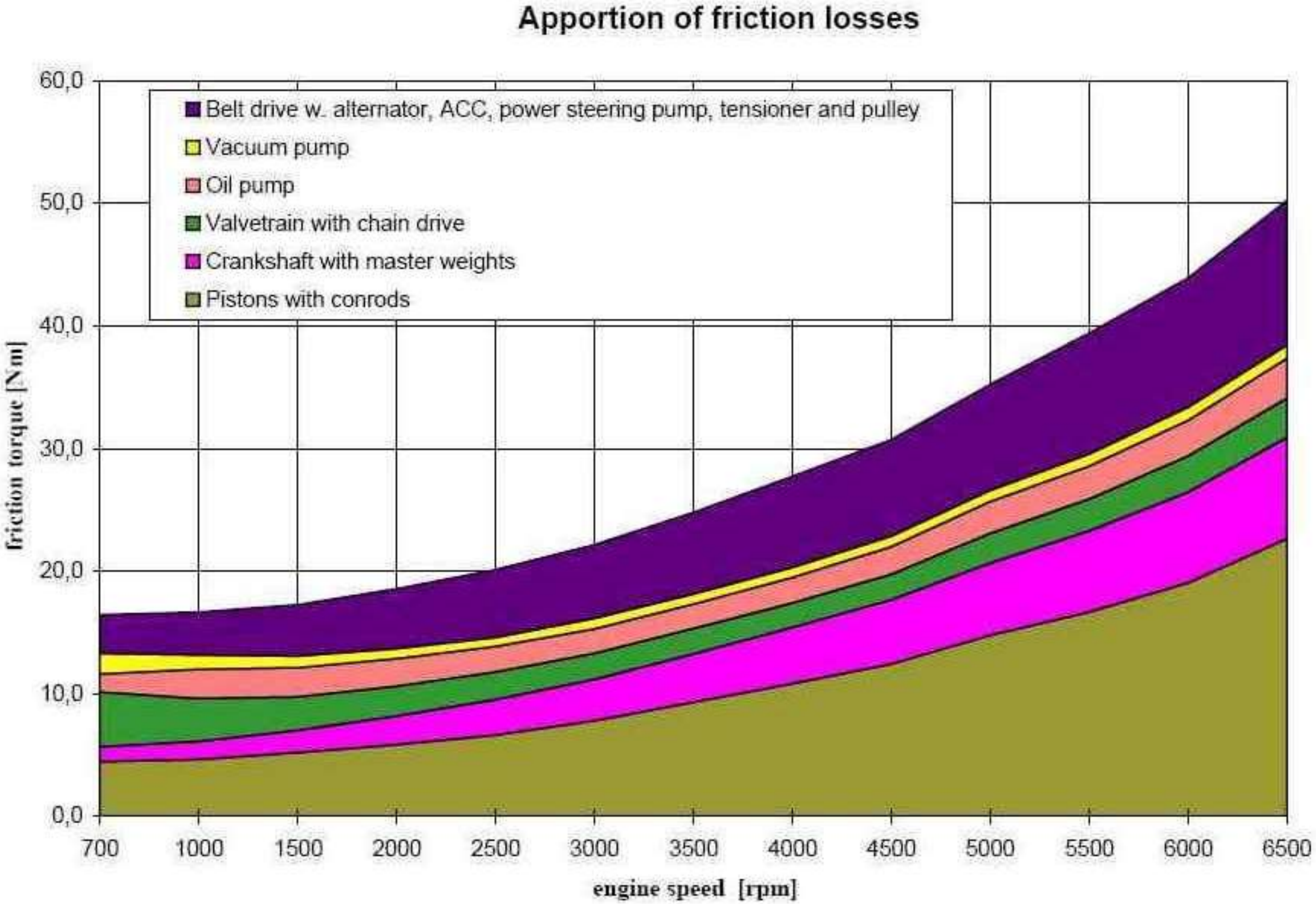
Friction Investigations

n.KW U/min	Md Nm Vacuum pump	Md Nm Pistons with conrods	Md Nm Crankshaft with master weights
700	1,7	4,5	1,2
1000	1,2	4,6	1,5
1500	1,0	5,2	1,9
2000	0,9	5,9	2,3
2500	0,8	6,6	2,9
3000	0,8	7,8	3,4
3500	0,8	9,3	3,9
4000	0,8	10,8	4,6
4500	0,8	12,4	5,2
5000	0,9	14,8	5,9
5500	1,0	16,7	6,6
6000	1,1	19,1	7,4
6500	1,1	22,6	8,3

n.KW U/min	Valvetrain with chain drive	Oil pump	Belt drive w. alternator, ACC, power steering pump, tensioner
700	4,5	1,5	3,2
1000	3,5	2,4	3,5
1500	2,7	2,4	4,2
2000	2,4	2,3	4,9
2500	2,3	2,1	5,5
3000	2,2	2,0	6,0
3500	2,1	2,0	6,7
4000	2,0	2,1	7,4
4500	2,1	2,3	7,9
5000	2,4	2,6	8,7
5500	2,8	2,7	9,9
6000	2,9	2,9	10,6
6500	3,2	3,3	11,8



Total friction losses at 90°C and 0.5 l oil level

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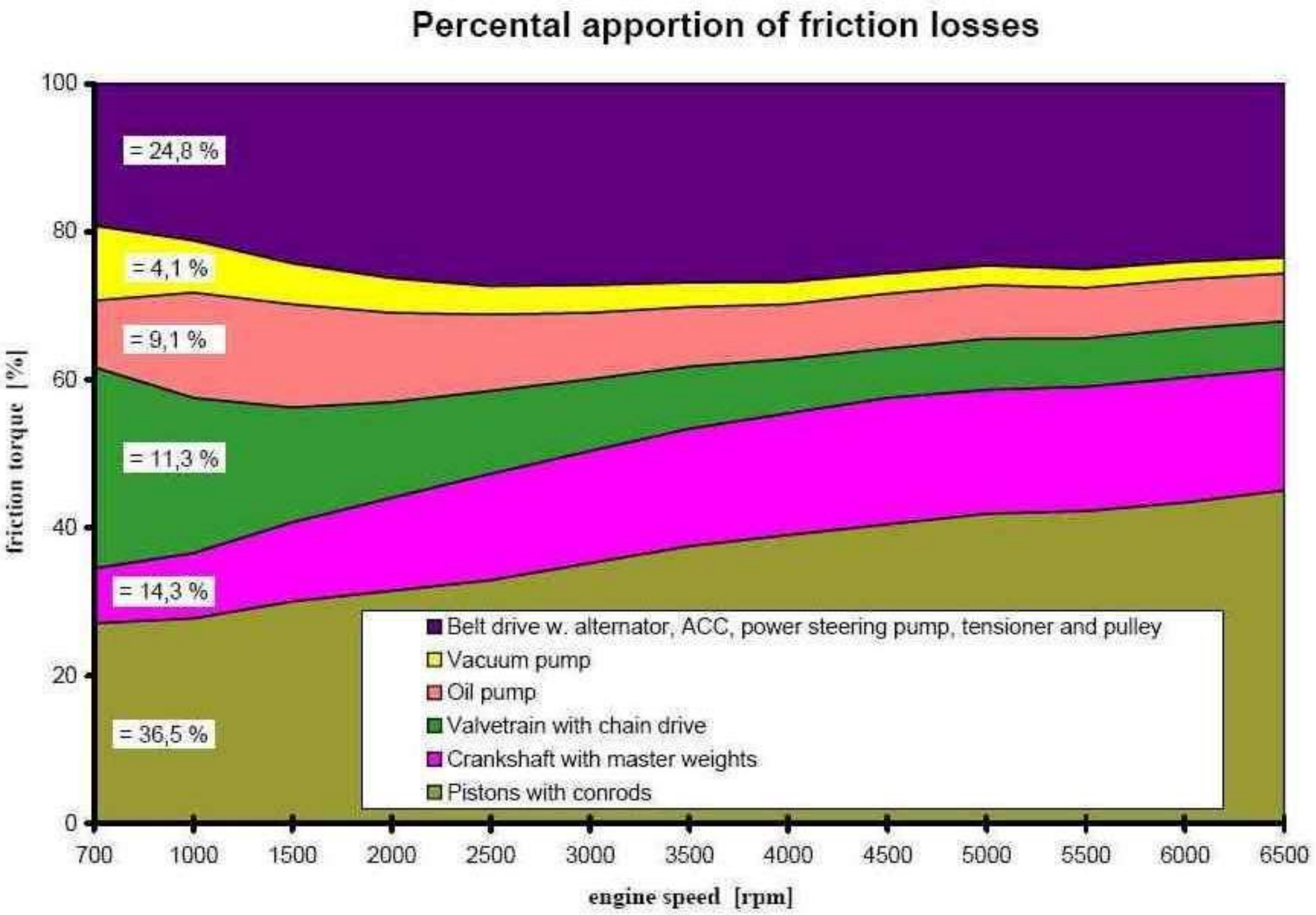
Friction Investigations

n.KW U/min	Md Nm Vacuum pump	Md Nm Pistons with conrods	Md Nm Crankshaft with master weights
700	10,2	27,1	7,4
1000	7,1	27,7	8,9
1500	5,6	30,0	10,7
2000	4,6	31,5	12,6
2500	3,8	32,9	14,4
3000	3,7	35,2	15,2
3500	3,3	37,5	15,9
4000	3,0	39,0	16,4
4500	2,7	40,5	17,1
5000	2,6	41,9	16,8
5500	2,5	42,3	16,8
6000	2,4	43,4	16,9
6500	2,1	45,0	16,4

n.KW U/min	Valvetrain with chain drive	Oil pump	alternator, ACC, power steering pump, tensioner
700	27,2	8,9	19,2
1000	21,0	14,2	21,2
1500	15,6	13,9	24,3
2000	12,9	12,1	26,3
2500	11,2	10,3	27,4
3000	9,7	9,0	27,2
3500	8,4	8,1	26,9
4000	7,3	7,4	26,8
4500	6,7	7,4	25,7
5000	6,8	7,3	24,6
5500	6,6	6,8	25,1
6000	6,6	6,7	24,0
6500	6,4	6,5	23,5



Total friction losses at 90°C and 0.5 l oil level

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Evaporative Emissions Detection

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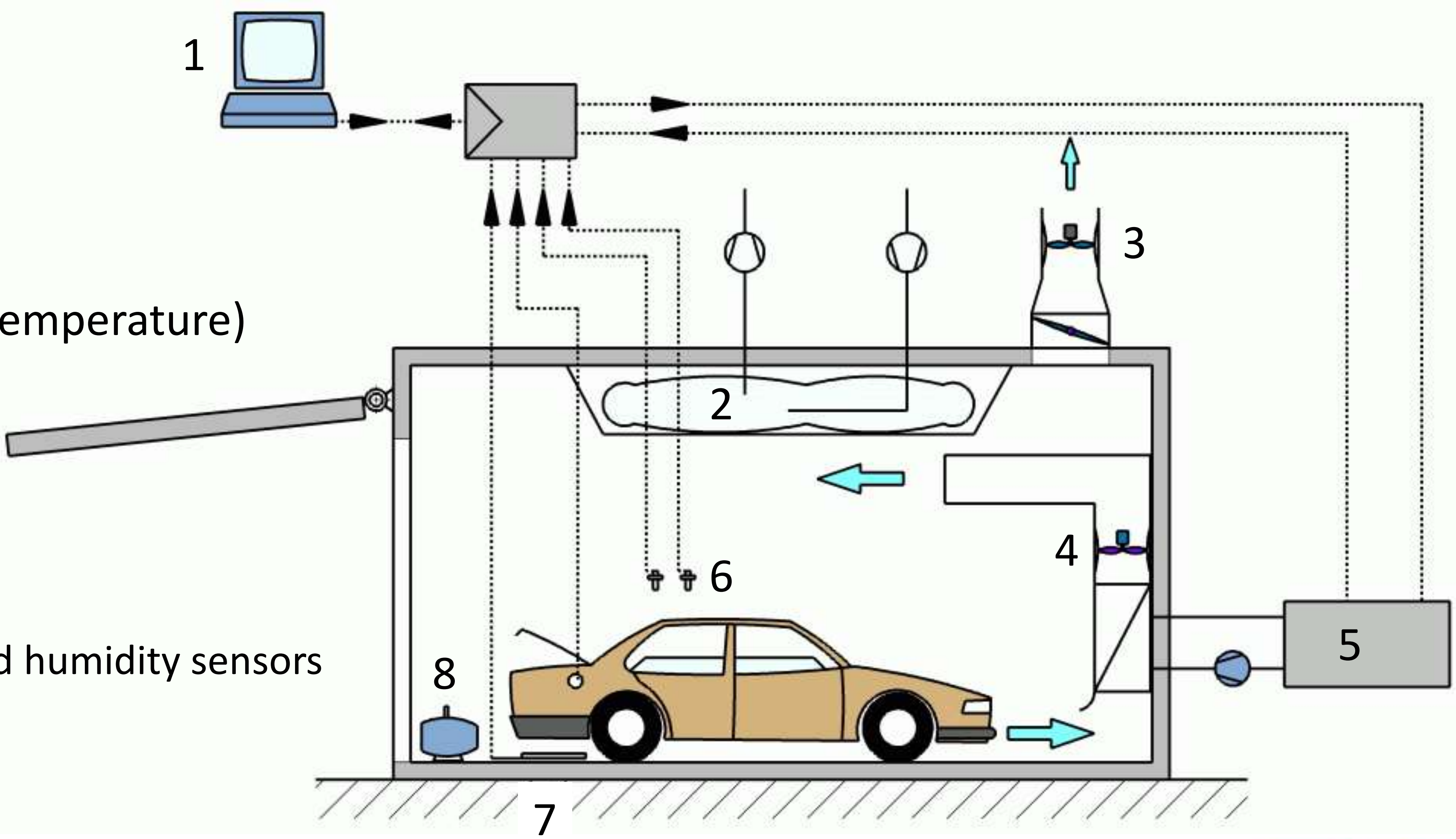
SHED system (Scheme)

(Sealed Housing for Evaporative emission Determination)



VT-SHED (variable temperature)

1 Computer
2 Air bag (4 m^3)
3 Purging fan
4 Mixing fan
5 Heating system
6 Temperature and humidity sensors
7 Heating mat
8 Blower

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SHED

SHED chamber and equipment

- Gastight, block-shaped measuring chamber
- Impermeable to hydrocarbons
- Temperature control system for temperature in chamber
- Pressure constant (Δ p ≤ ± 5 mbar): Compensation of volume
- FID-analyser: Measurement of HC-concentration
- Heating system for fuel (optional)
- Temperature sensor: Temperature of chamber and fuel
- Equipment for recording pressure Δ p
- Fans for purging and mixing
- Equipment for determination of absolute humidity

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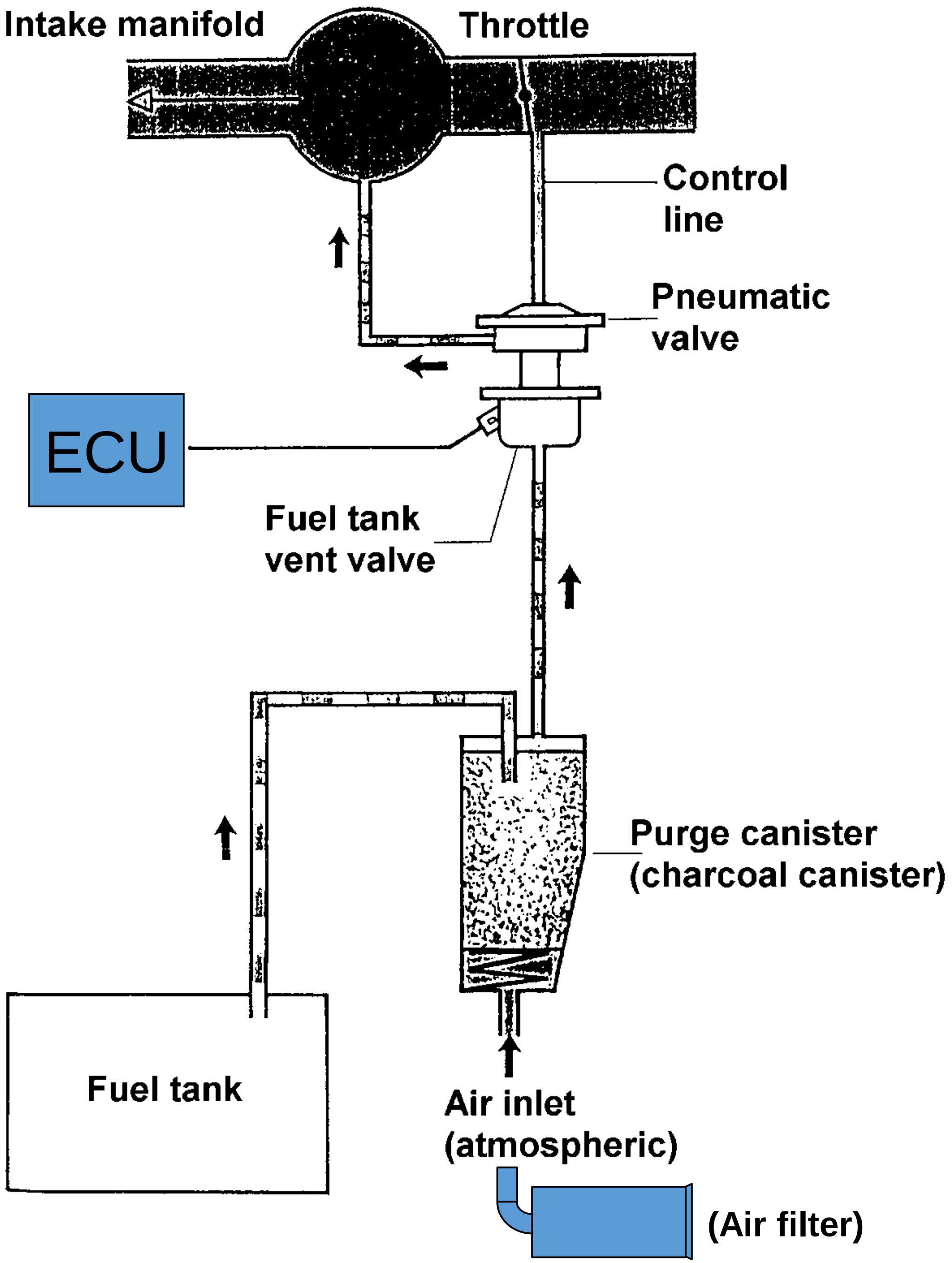

SHED

- Activated carbon trap

Evaporative Emission Control System (EVAP)

Types of losses:

- Running losses
- Diurnal losses
- Hot-soak losses

Prove of:

- Recovering capacity
- Storage capacity

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SHED

Purge canister
(cut away)

tank leak diagnostic module

3. chamber coal type II

2. Chamber coal type I

1. Chamber coal type I

spring loaded preload plate

- Volume:
- ECE: About 1 l
- US: About 4 l (because of ORVR)

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SHED

- Loading of purge canister

Purge canister normally loaded in vehicle, if access bad → dismount it, load it outside vehicle

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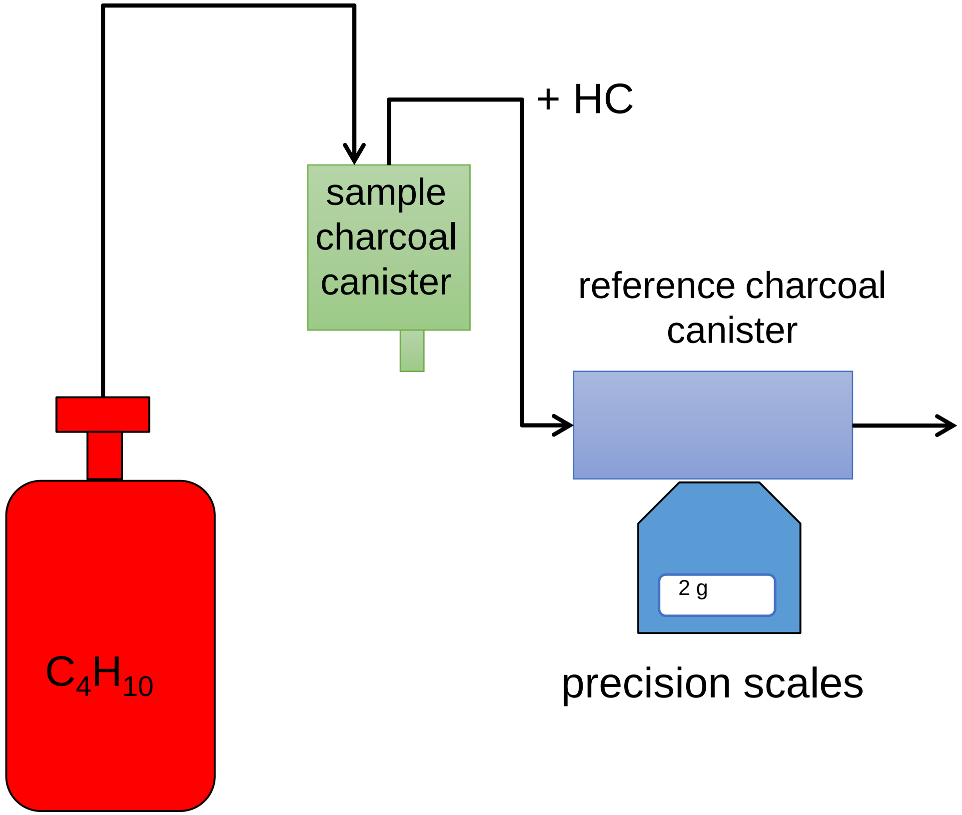
SHED



Creating and detecting breakthrough of purge canister (schematic)

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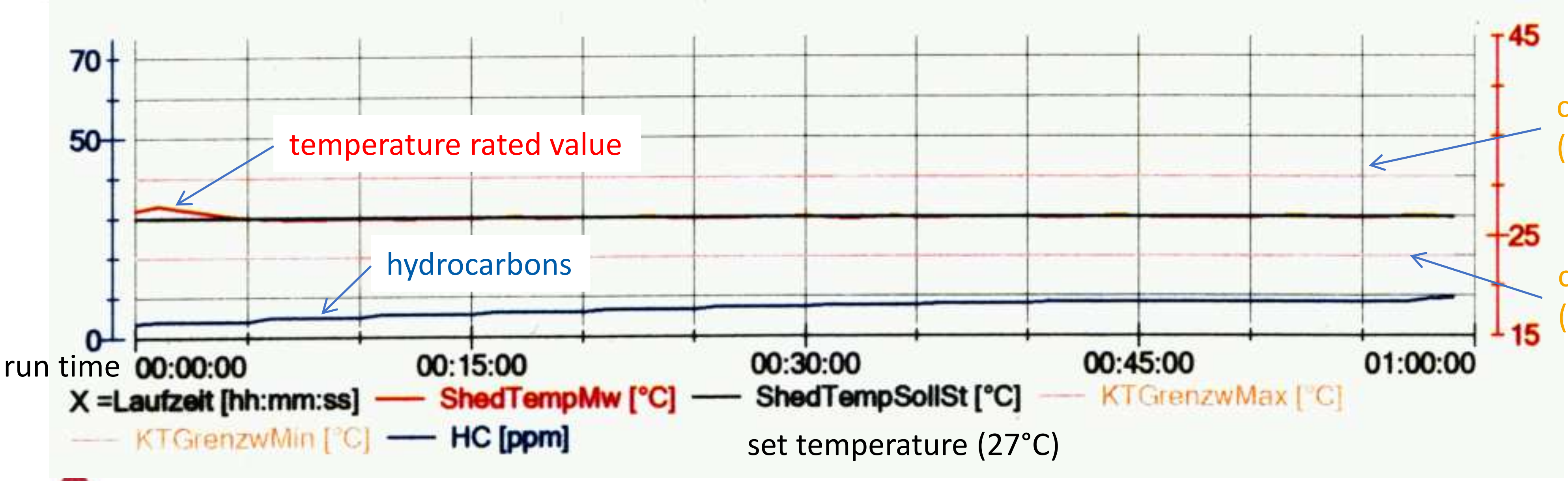
SHED

		Beginn	Ende 1	Ende 2	Ende 3
Date:		16.05.2008	16.05.2008		
Time :		12:44:00	13:44:00		
Chamber temperature:	°C	27,77	26,99	0,00	0,00
Chamber pressure:	kPa	96,82	96,83	0,00	0,00
HC concentration:	ppm	3,69	9,38	0,00	0,00
HC mass:	g		0,202	0,000	0,000
Mass purge canister:	g	0,00	0,00		

Example Hot-Soak Test



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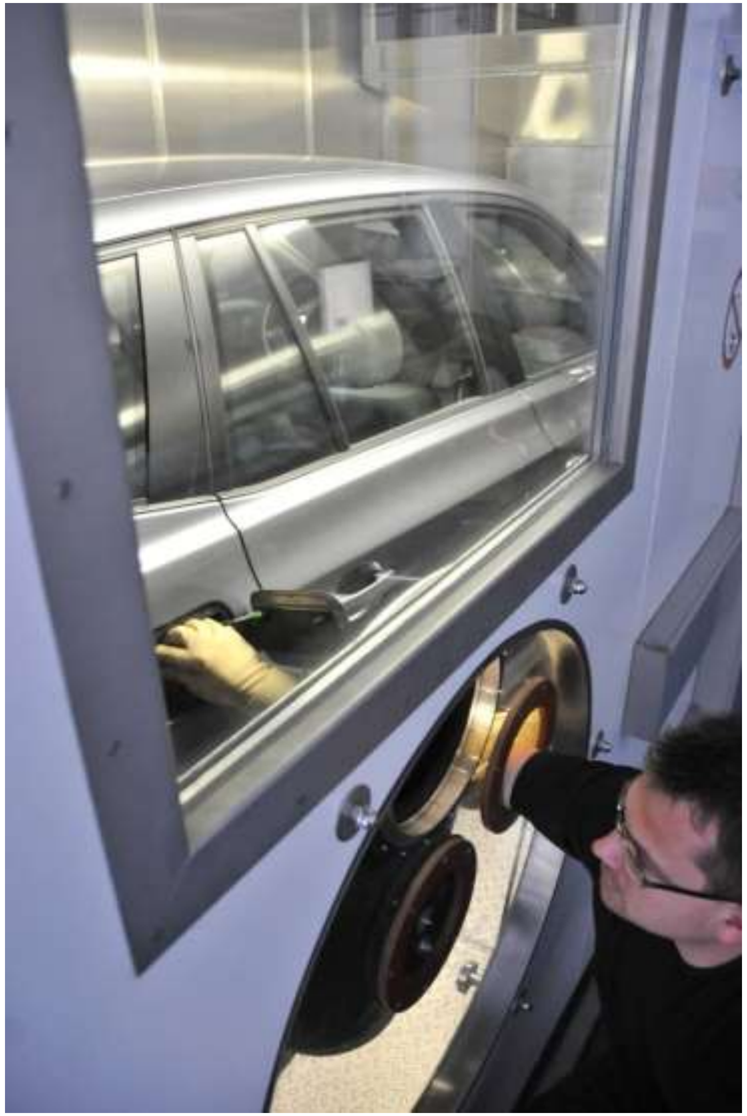
On-board Refuelling Vapour Recovery (ORVR)



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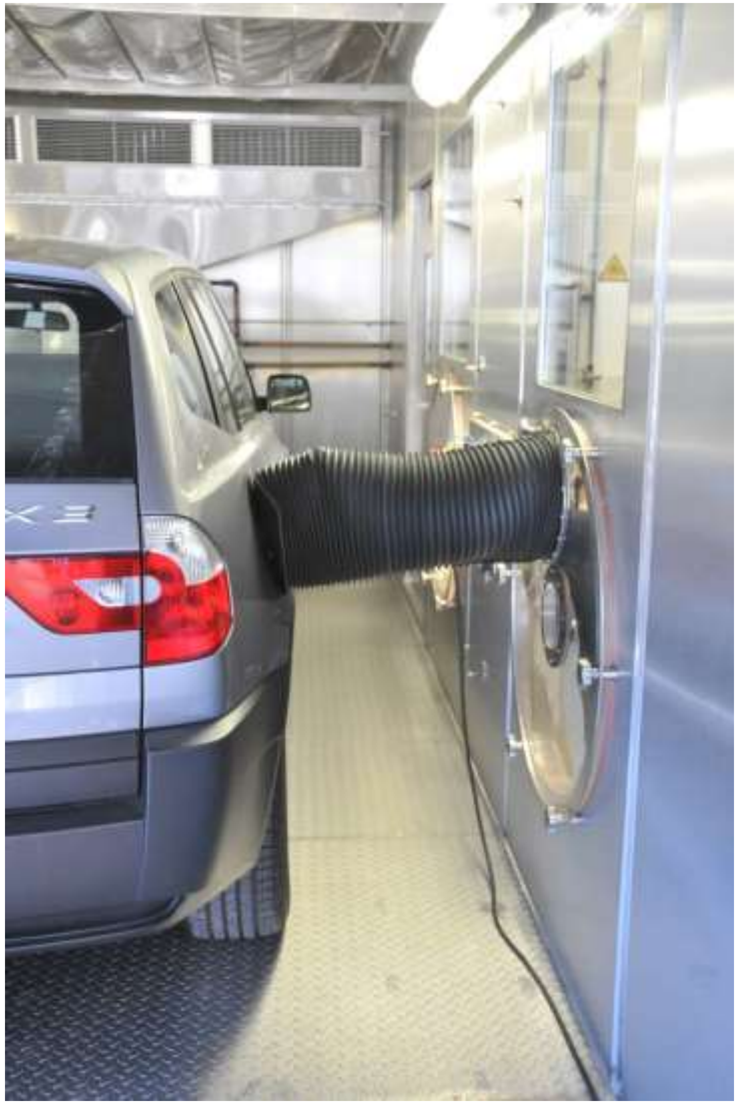
ORVR



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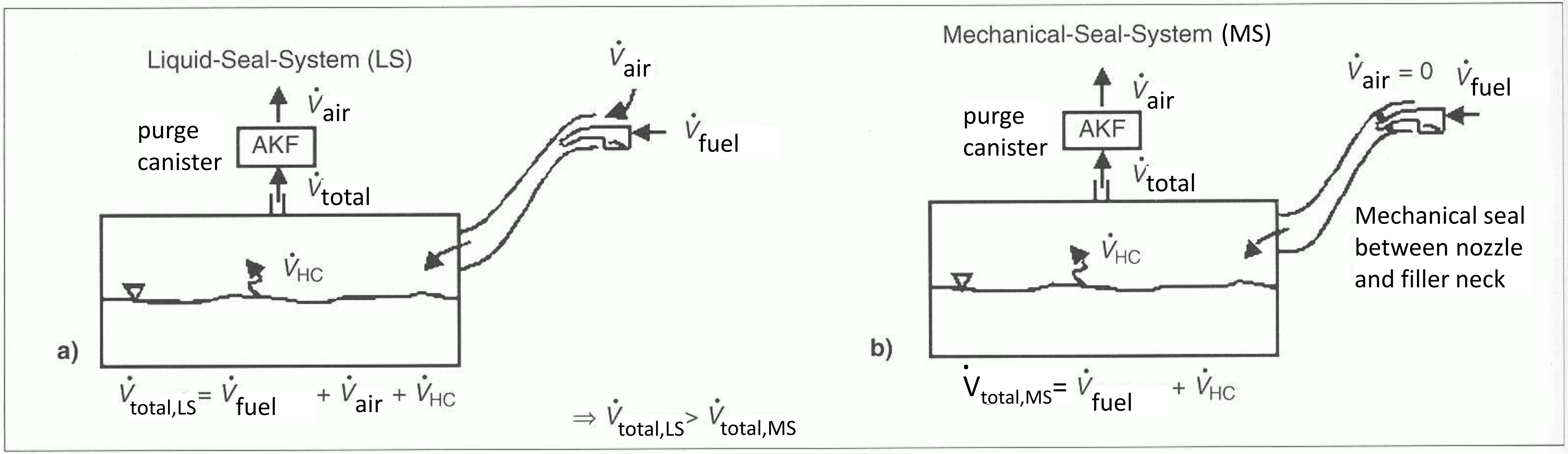
ORVR



Sealing systems during on-board refuelling

ORVR hot: $\dot{V}_{fuel} = 15$ to 38 l/min
$T_{fuel} = 38°C$

2. R&D-related Projects

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Real-time measurement of drive-line torque

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Real-time measurement of drive-line torque

- Cooperation with engineering service provider
- Government-funded project
- Objectives:
    - Simple and cost-effective solution for reading torque value in
    - power train for control systems
    - Useful for real-driving emissions (RDE) applications, energy management of battery-electric vehicles (BEV), etc.

Test setup drive-line torque

Position sensors pick-up point B01 in x, y, z direction

Interfaces for inverter and data logger

Complete Renault Twizy drive line

Position sensors B03 in x,y,z direction

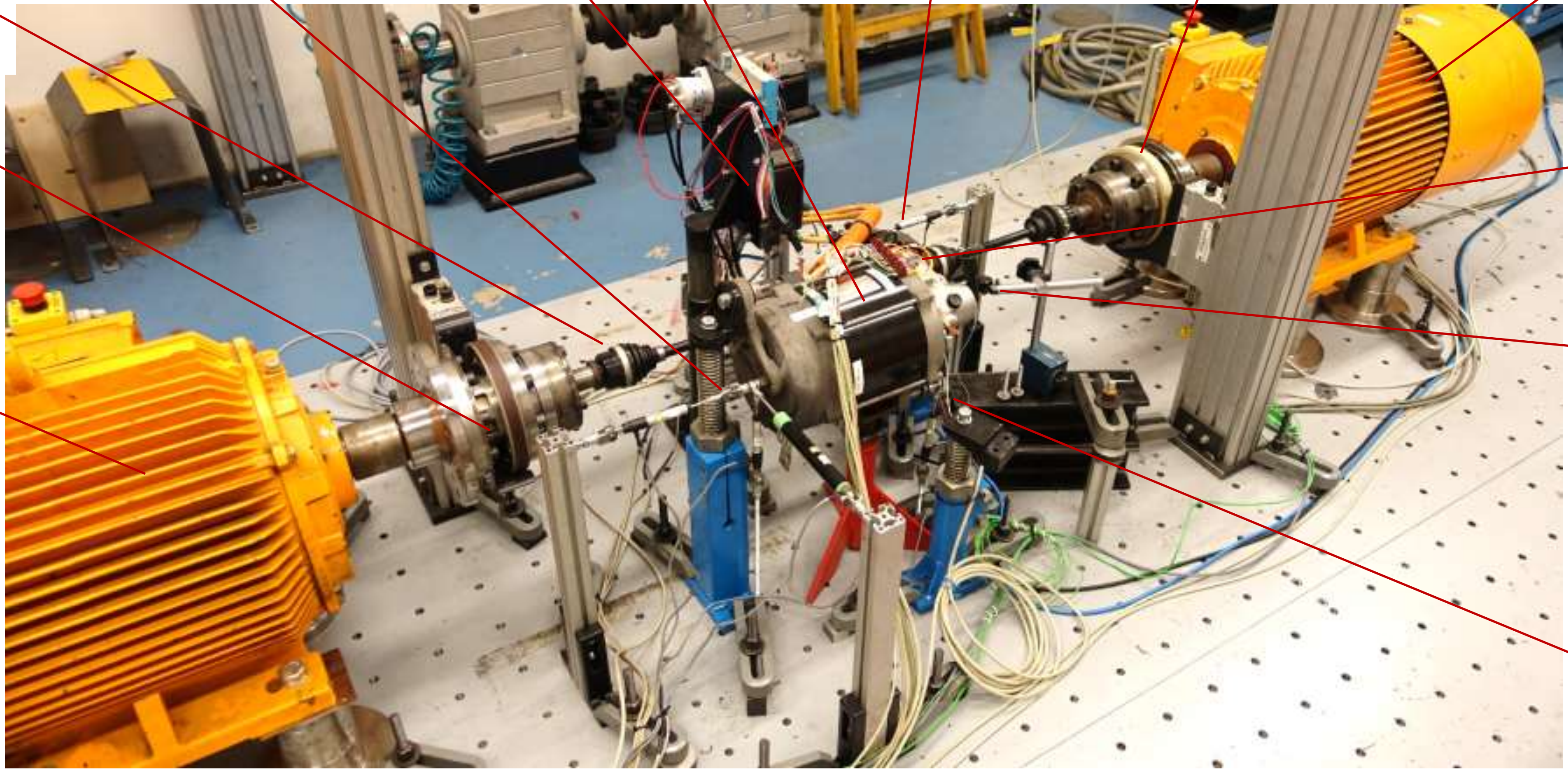
Torque flange left-hand

Power absorber left-hand wheel

Stock drive shafts

Torque flange right-hand

3 strain gauges on transmission case



Power absorber right-hand wheel

Automotive angular sensor

Position sensor B02 in z direction

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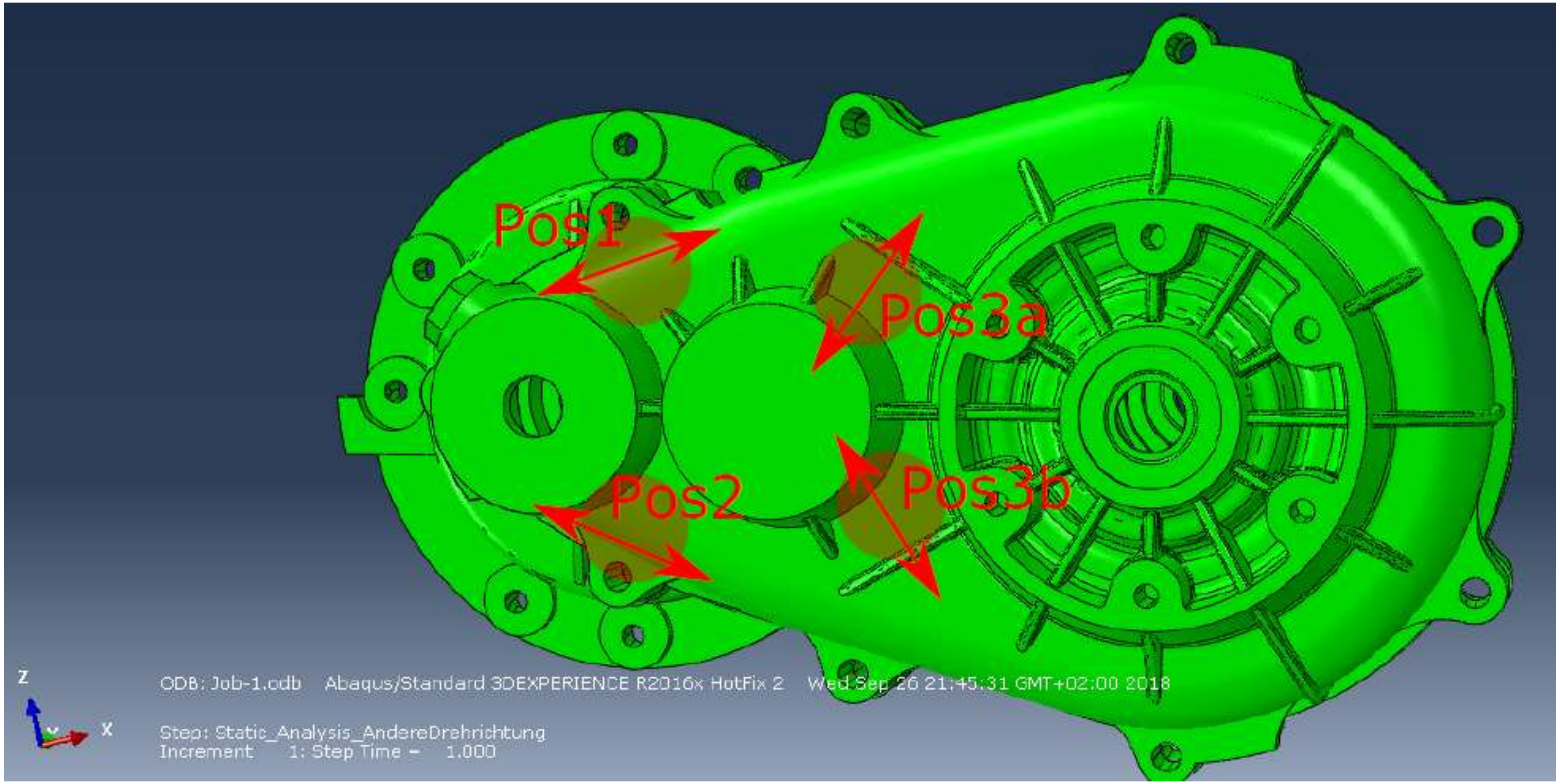
Test setup drive-line torque



Locations of strain gauges

Pos1 and Pos2: 90° rosette
Pos3a: 3-axes rosette
Pos3b: Not mounted

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Tyre measurement

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Tyre measurement

- Cooperation with manufacturer of (rental) karts
- Idea of government-funded project was declined
- Objectives of main project:
  - Setting-up app for customers
  - Tyre data needed for mathematical model
  - Simple and cost-effective method of obtaining tyre data
  - Creating mathematical vehicle model, simulation of lap times

→Task for sub project: Design and build test vehicle

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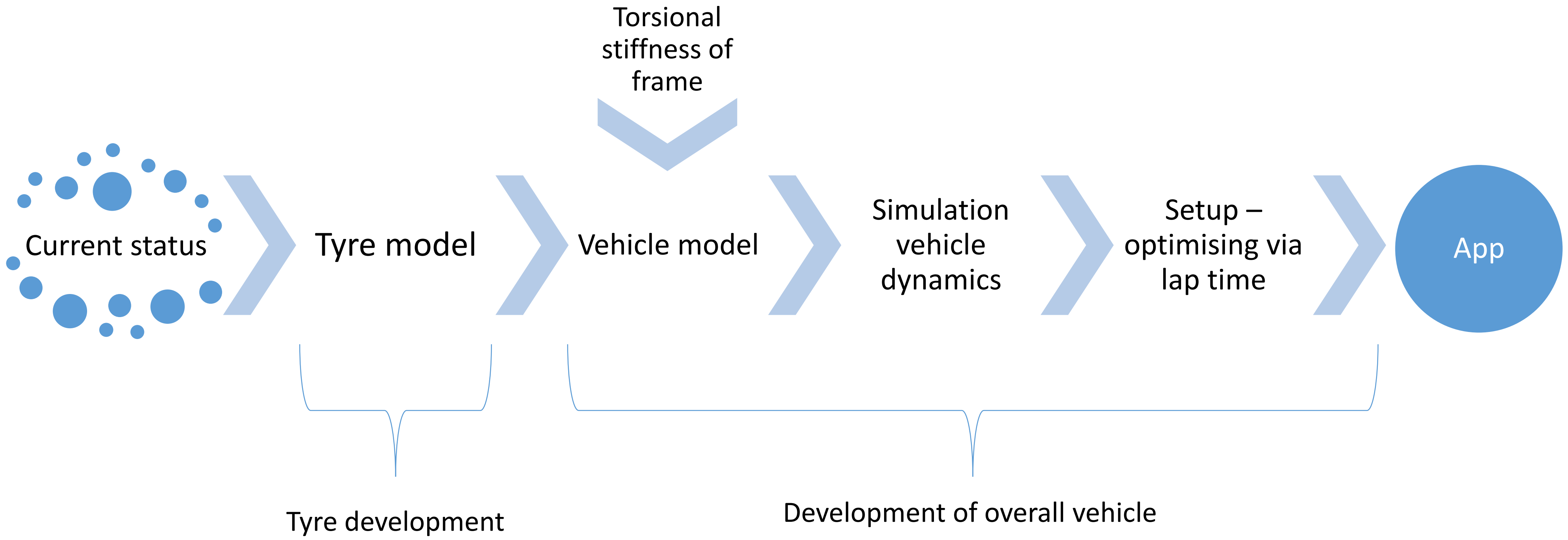
Tyre measurement

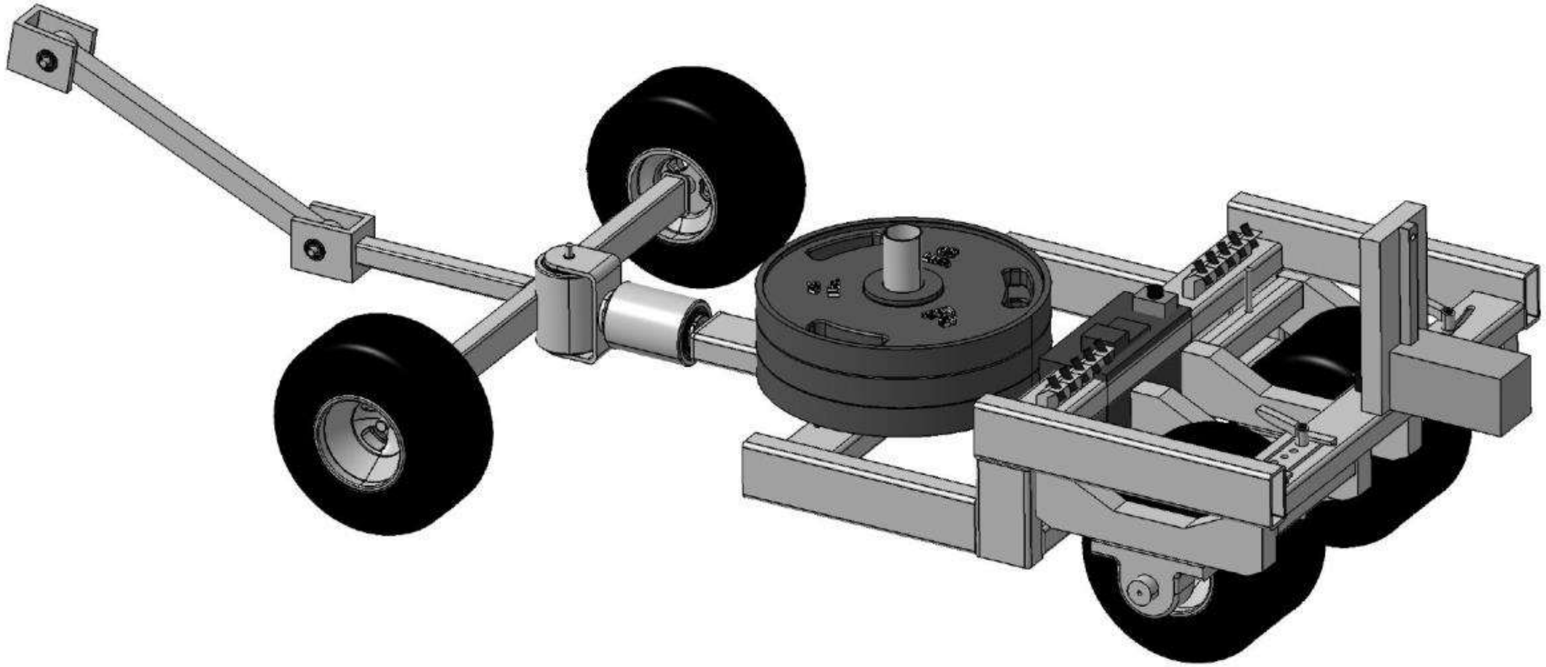


Roadmap main project

Tyre measurement

Concept stage

1. First idea was 3-wheeled e-kart, with measuring wheel in the rear
2. Trailer guiding measuring wheel
3. Articulated trailer with symmetric arrangement of rear wheels



Design of measurement trailer

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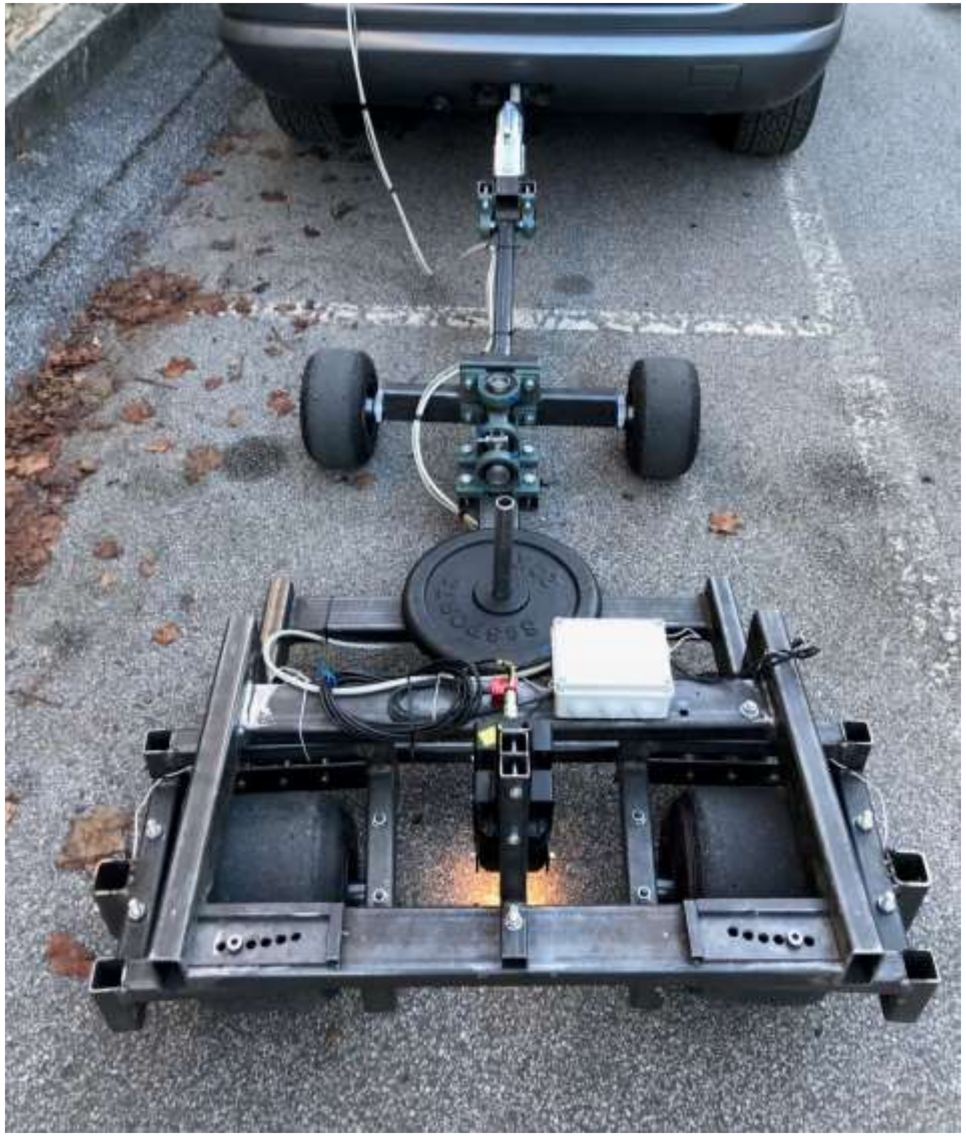
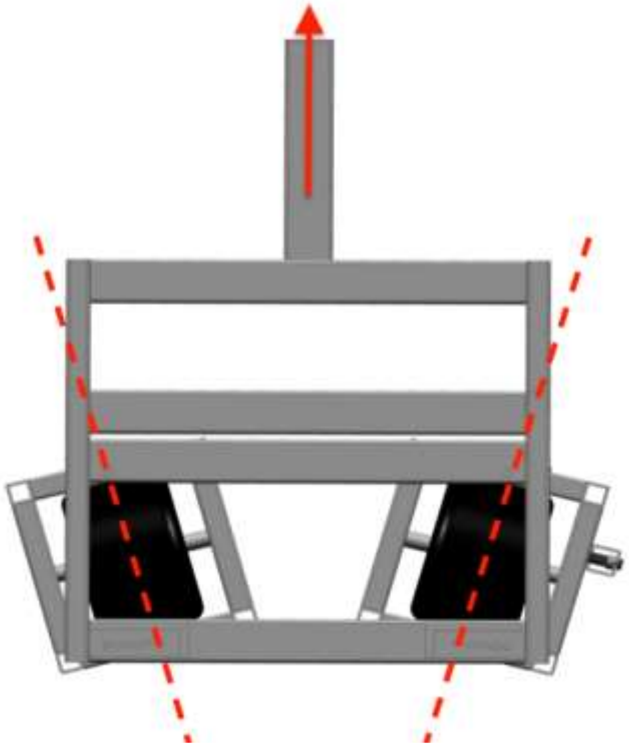
Tyre measurement





Investigation: Influence of alignment of rear wheels

Measurement runs

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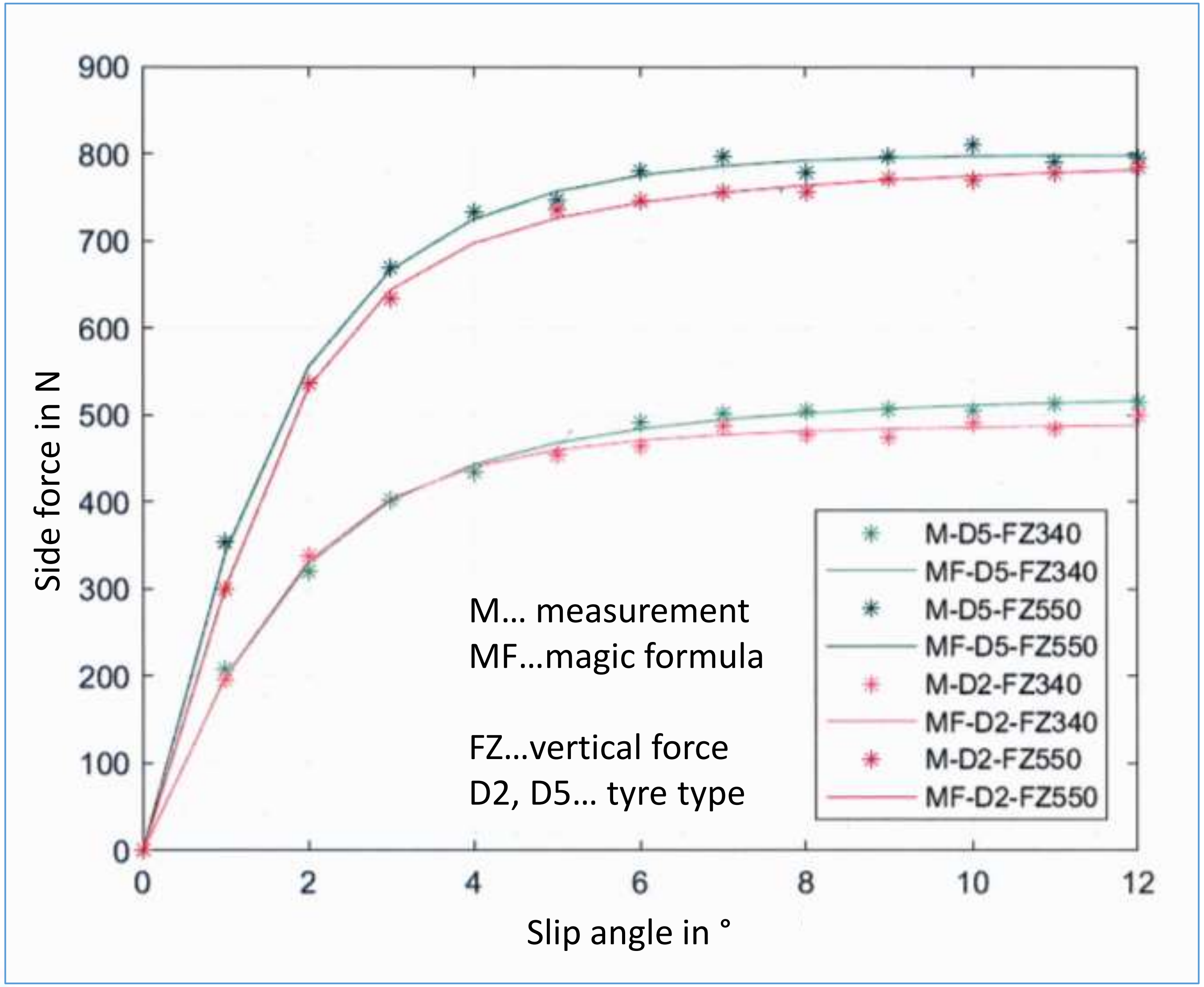
1st Test

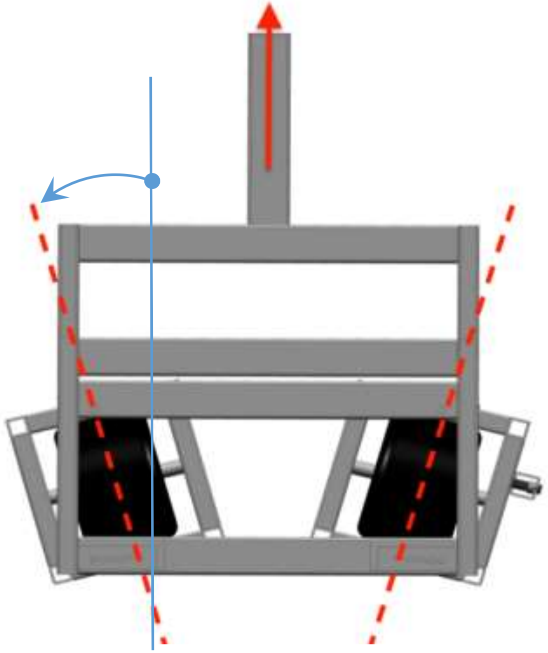
FH | JOANNEUM

3rd Test

FH | JOANNEUM

Tyre measurement





Definition of tyre slip angle

Results

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E-Drive Measurement

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E-Drive Measurement

The task of the project is to determine the efficiencies of an electric powertrain.
This consists of:

- inverter
- electric motor
- gear box

In order to make the determination of the power losses more apparent, the temperature of individual components as well as the vibrations were recorded and evaluated.

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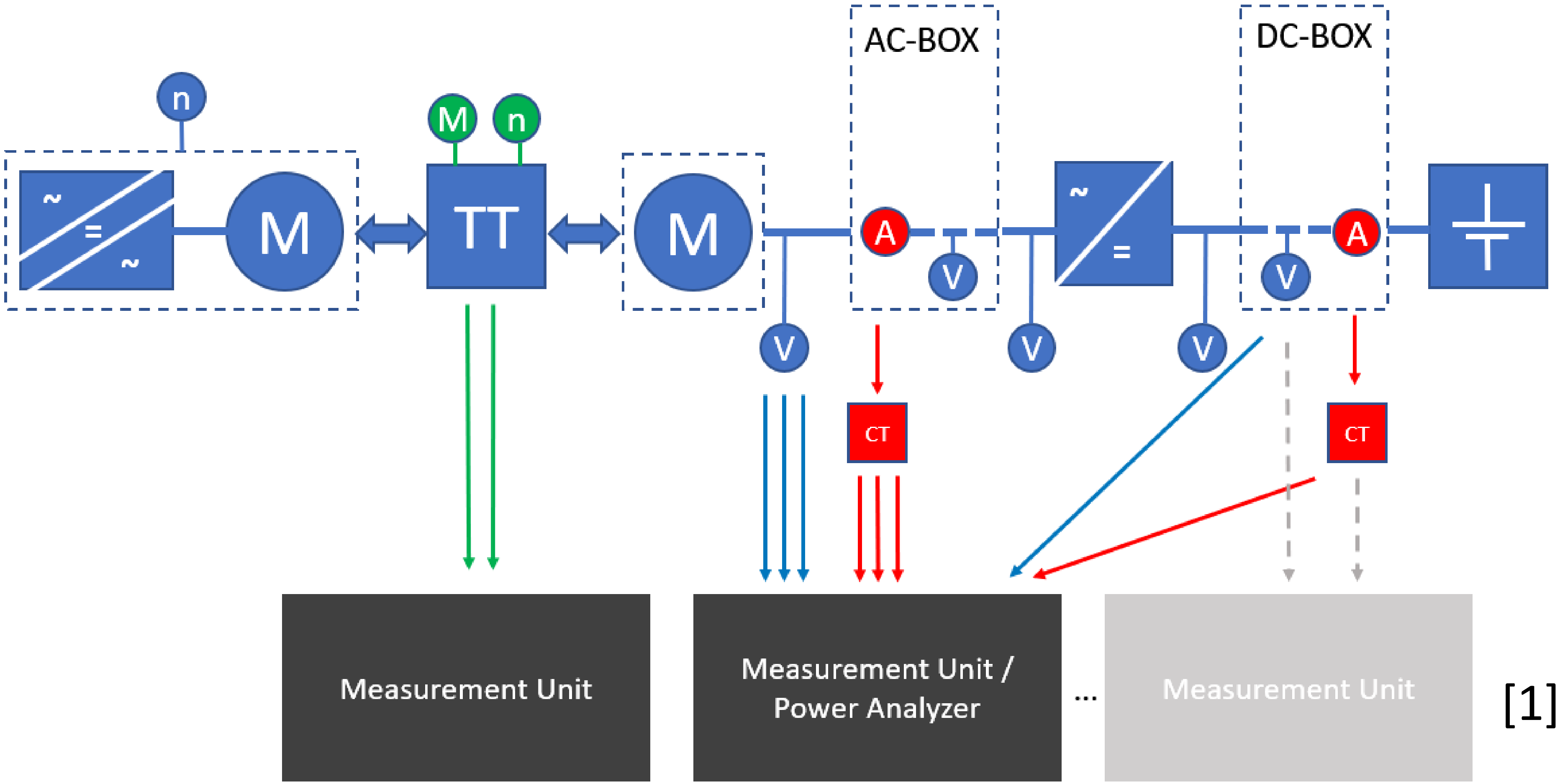
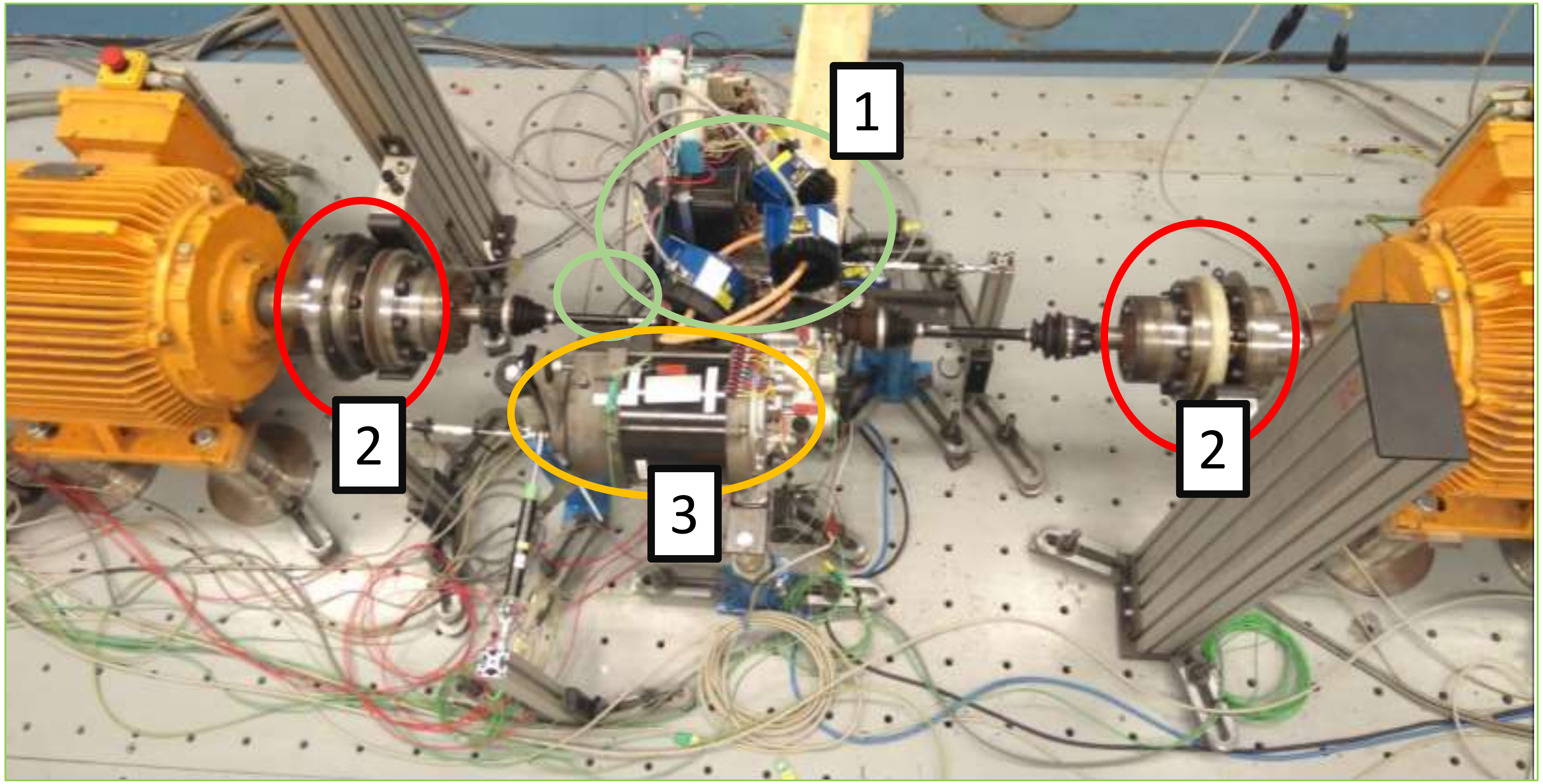
E-Drive Measurement



[1]

E-Drive Measurement

- Current measurement System
- Torque measurement System
- DUT (device under test)



Results

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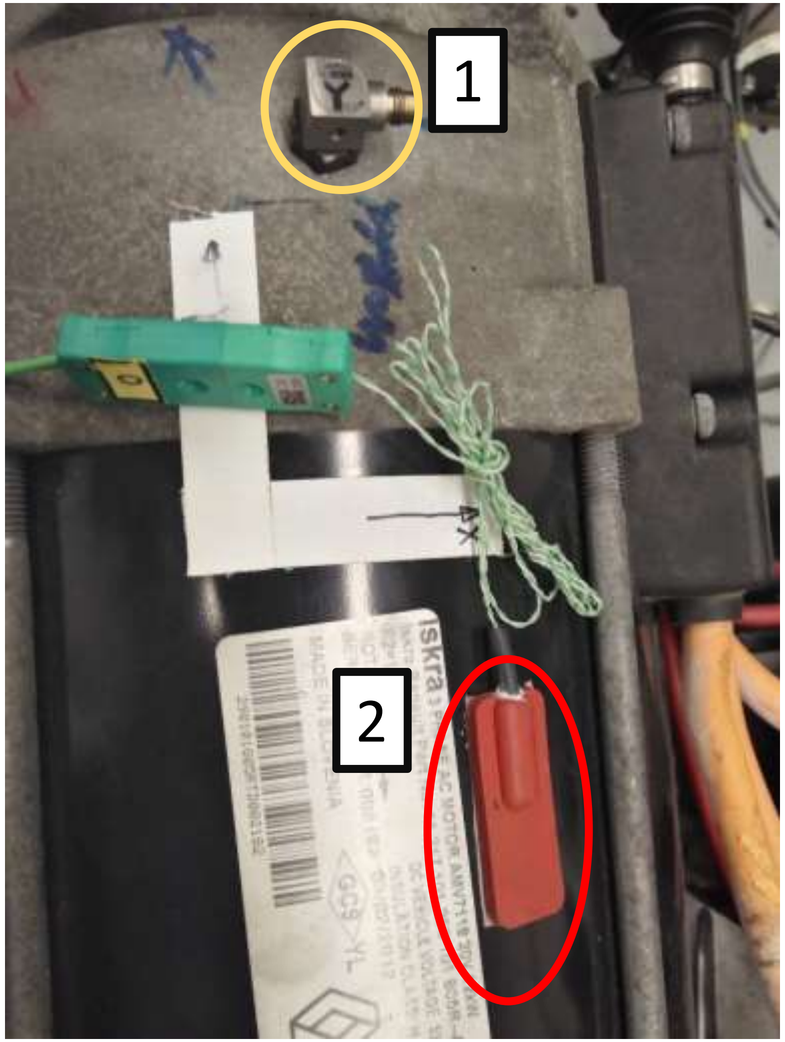
E-Drive Measurement

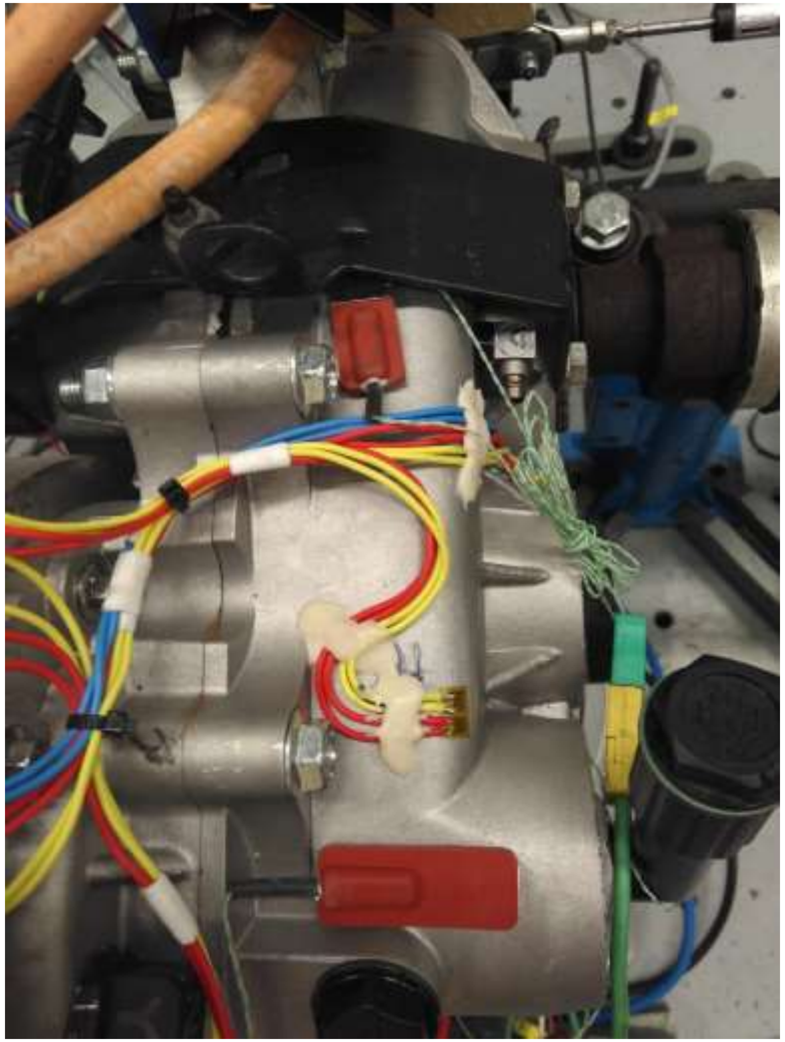


1) Acceleration Sensor:

to measure the intensity of the vibrations. The measurement takes place in three axes.

2) Temperature Sensor

Thermocouple Type K (TC)



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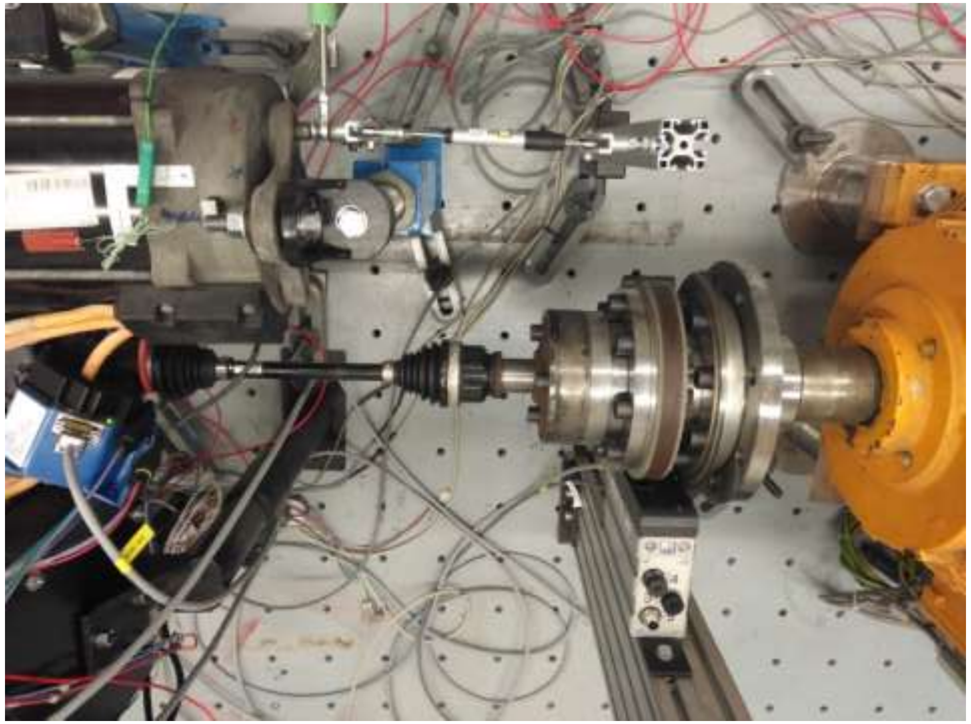
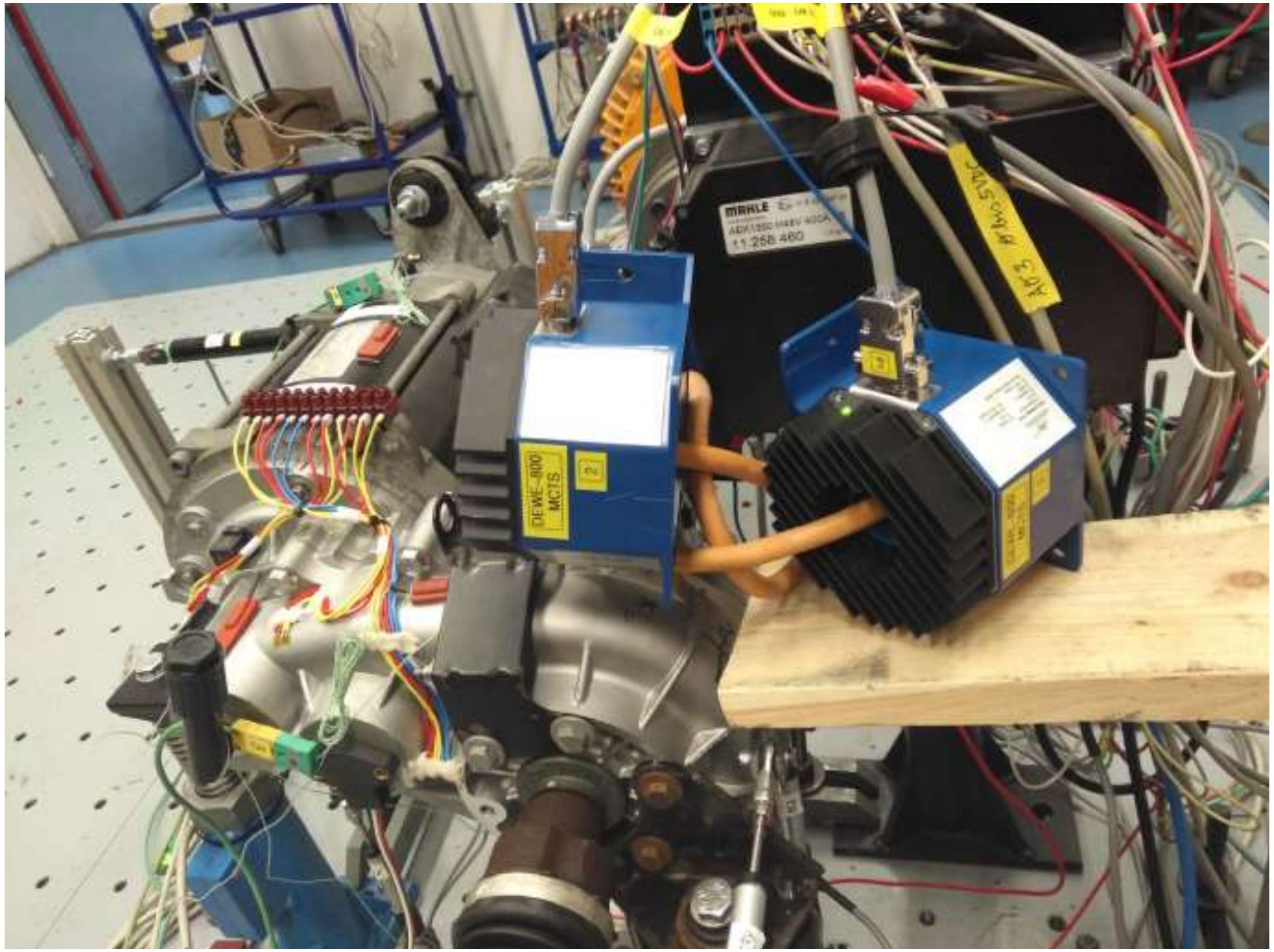
E-Drive Measurement



Digital Torque Transducer from HBM
Model: T12
Input = Torque
Output = Frequency or Voltage

-5000 Nm	→	30 kHz	or	-10 V
0 Nm	→	60 kHz	or	0 V
5000 Nm	→	90 kHz	or	10 V

E-Drive Measurement



Zero-Flux Current Transducers
Model: PM-MCTS 1000
Input: Current
Output: Voltage
Range:

DC, Peak up to 1000A
RMS Sinus up to 700A

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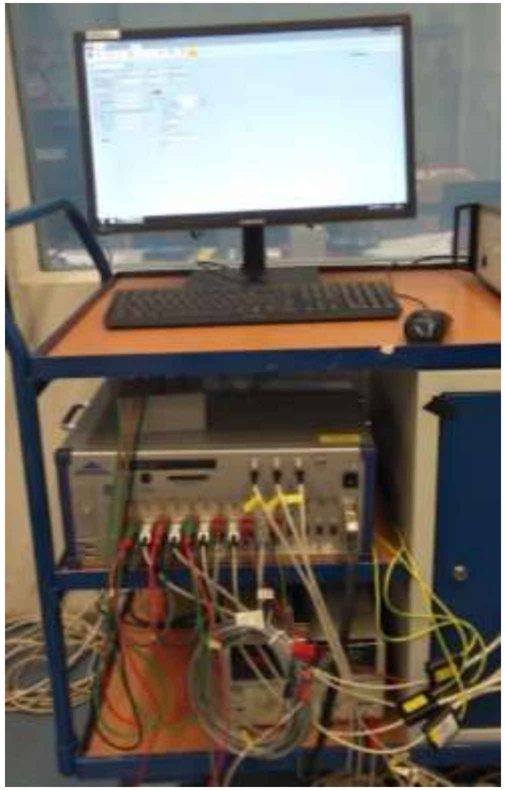
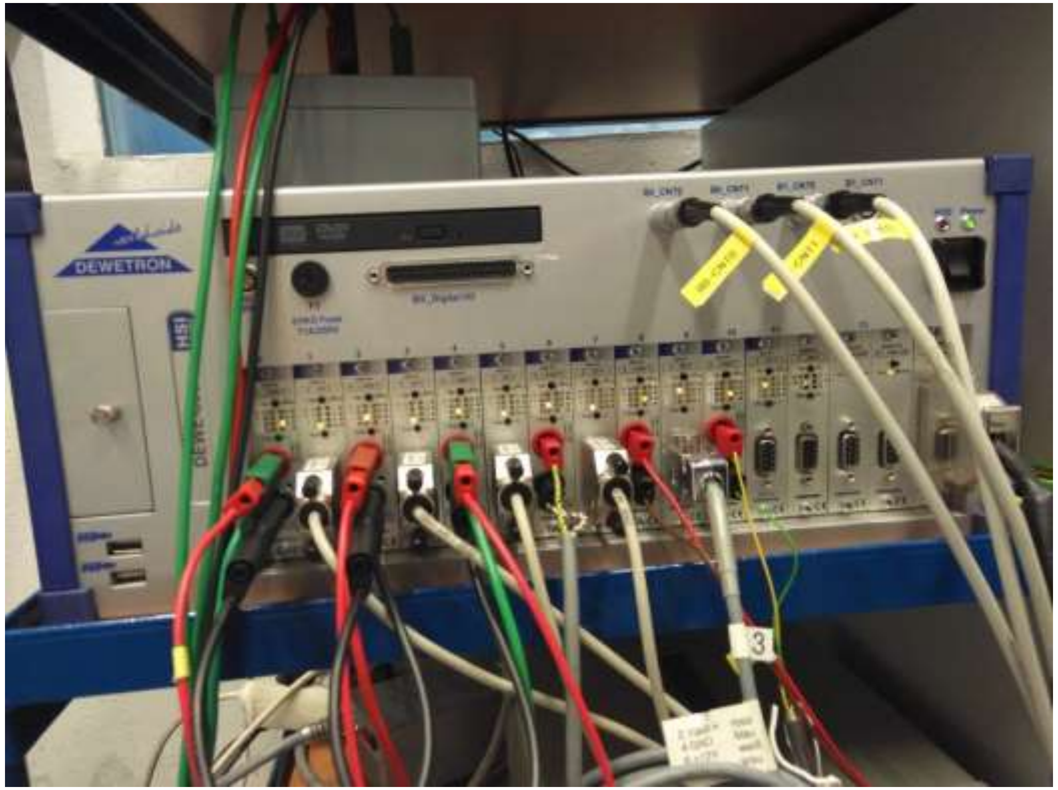
E-Drive Measurement

Data Acquisition System: Dewetron DEWE 800

Measure Module

- For Voltage:	HSI-HV Module	Input range: ±1400V
- For Current:	HSI-LV Module	Input range: 10mV up to 50V





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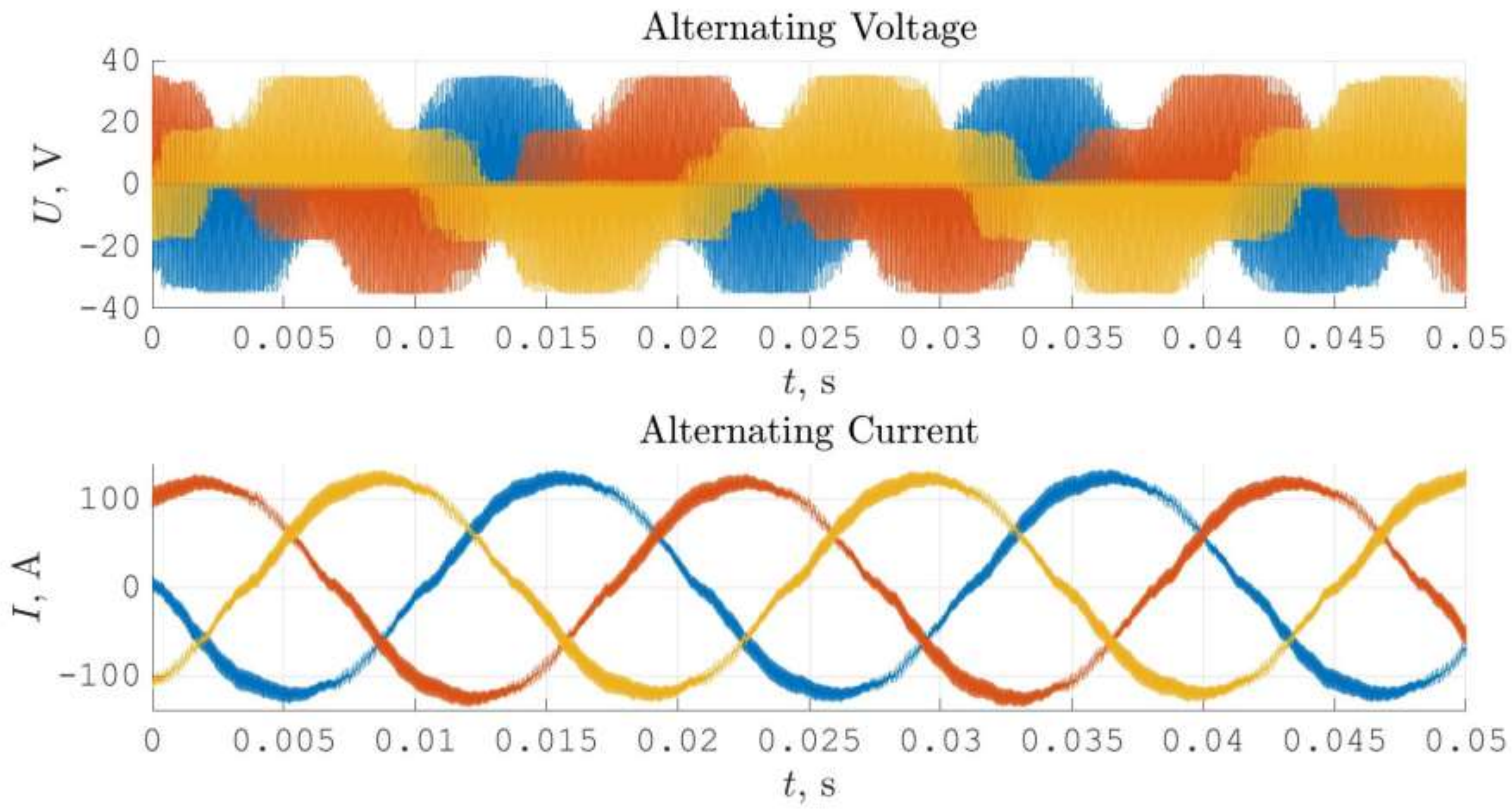
E-Drive Measurement



AC-Measurements
- Sample rate 200 kHz
- Electric Power can be calculated as a product of voltage and current

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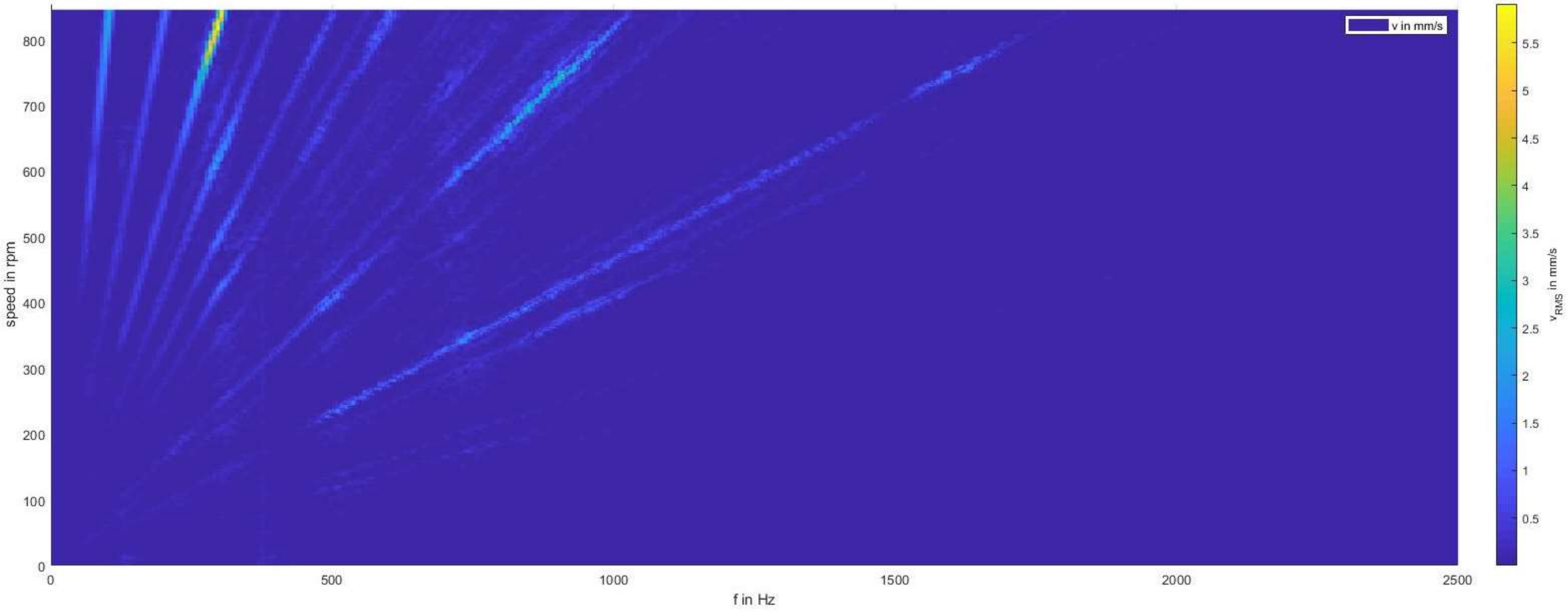
NVH-Analyses to check the mechanical system before tests



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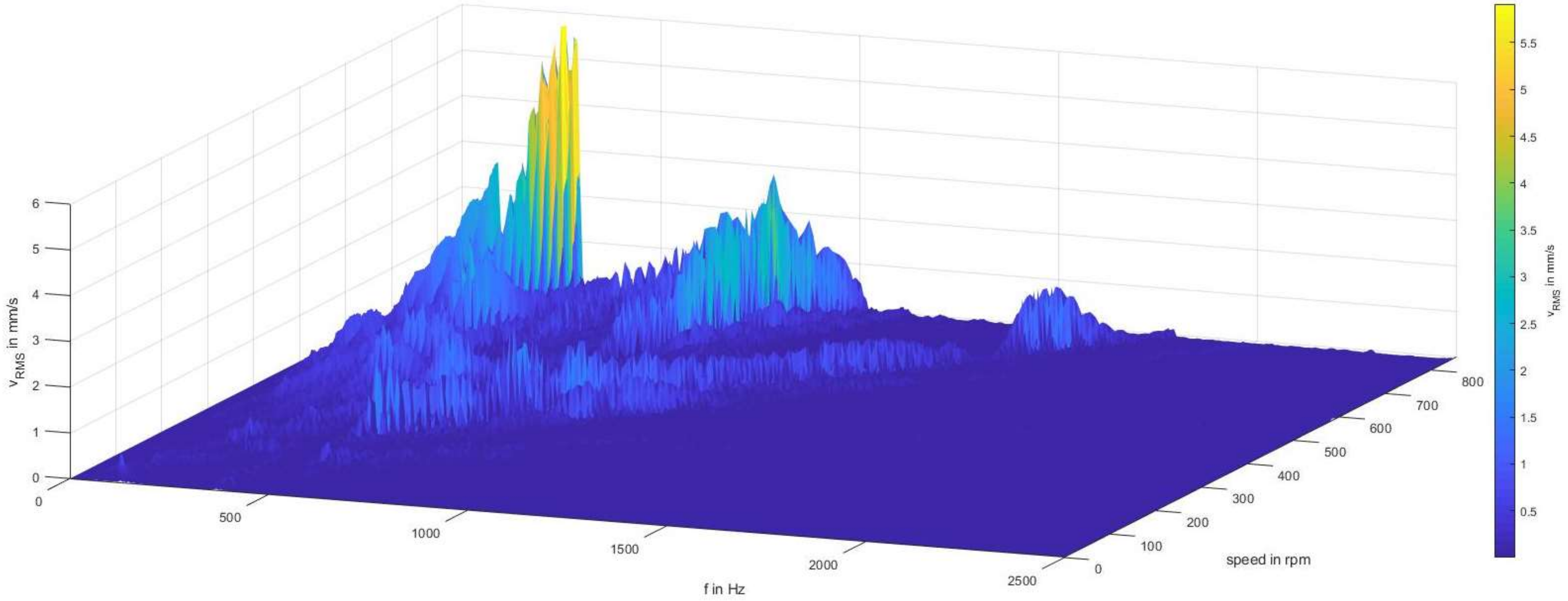
NVH-Analyses to check the mechanical system before tests



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References

- [1] Wiedner, Christoph: *THE CHALLENGES OF ANALYZING THE EFFICIENCY OF ELECTRICAL POWER TRAINS*. DEWETRON GmbH, 2018

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3. Educational-based Projects

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Gearbox Efficiency Improvement

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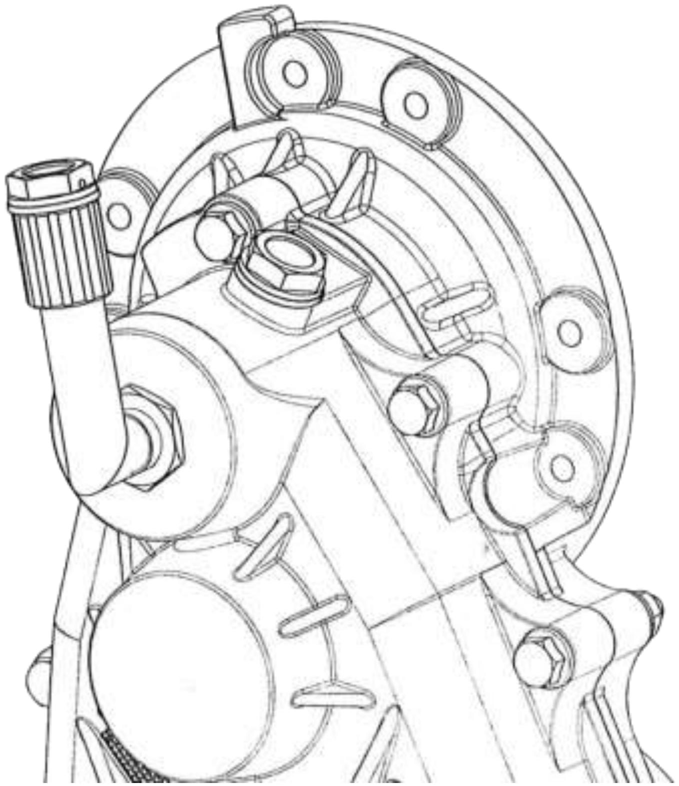
Gearbox Efficiency Improvement

At the Institute a prototype car (CULT) was adapted from a CNG combustion engine concept into an electric drive concept with two independent drives, each like used in Renault Twizy. The chassis was sponsored by Magna Steyr.

The main goal of the project is to improve efficiency of the gearboxes which are connected to the electric engines. A test bench setup and testing procedure has been defined, to achieve this task. Additionally, a gearbox adapter was designed and will be built. The gearbox contains power losses in spur gears, ball bearings and seals. Possible improvements to these losses as well as to oil lifetime are 3D printed oil guidance and oil reservoirs, which are evaluated and designed here.



Task description

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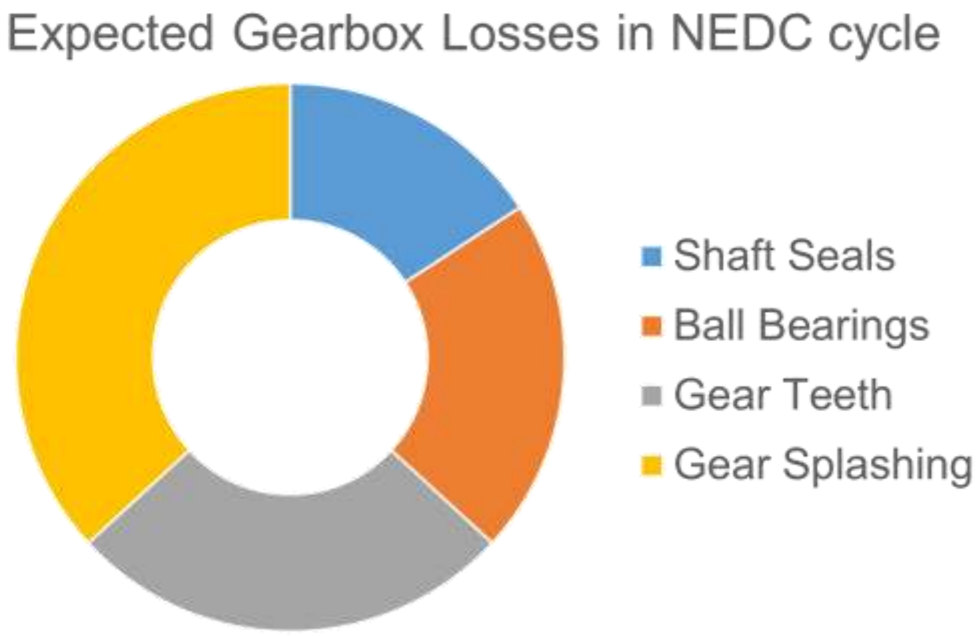
Gearbox Efficiency Improvement



Every gearbox creates power losses in its components, e.g. bearings, seals and gears. Frictional losses occur in the rubber seal to rotating shaft interaction, in the ball bearing contact area and the gear mesh, especially under load. Additionally, churning losses are present when gear teeth submerge into the oil sump. The losses can be divided into static and dynamic losses. Static losses are found in the seal shaft interaction and during churning. Dynamic losses are present in the gear tooth interaction and bearings under load.

Losses

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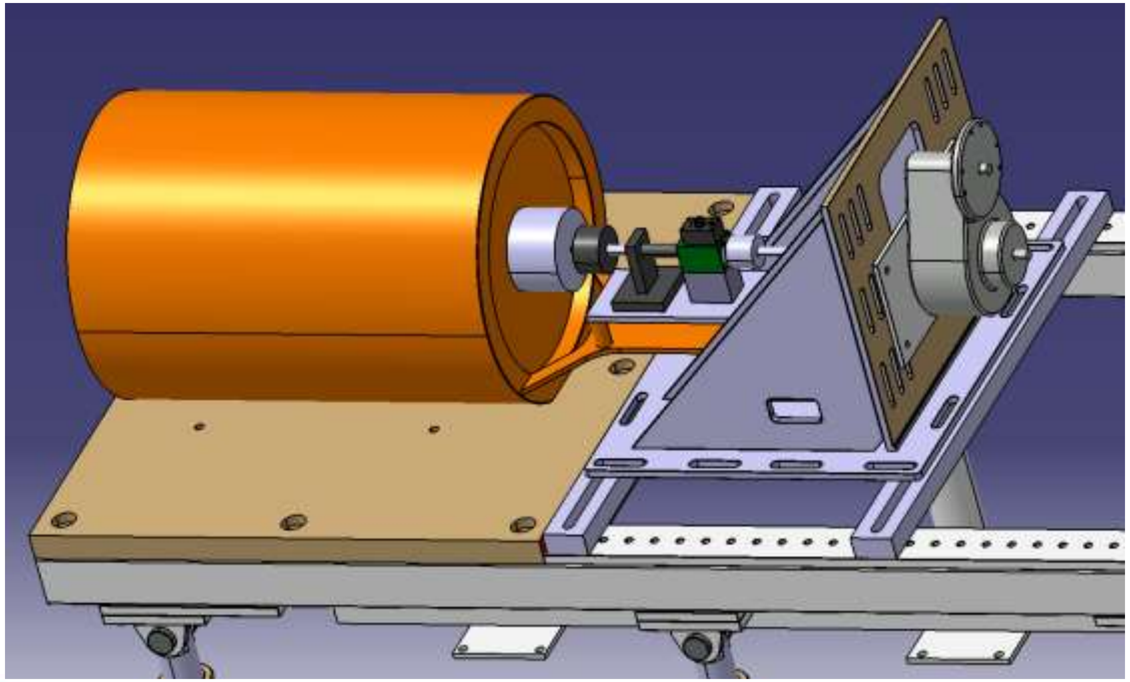
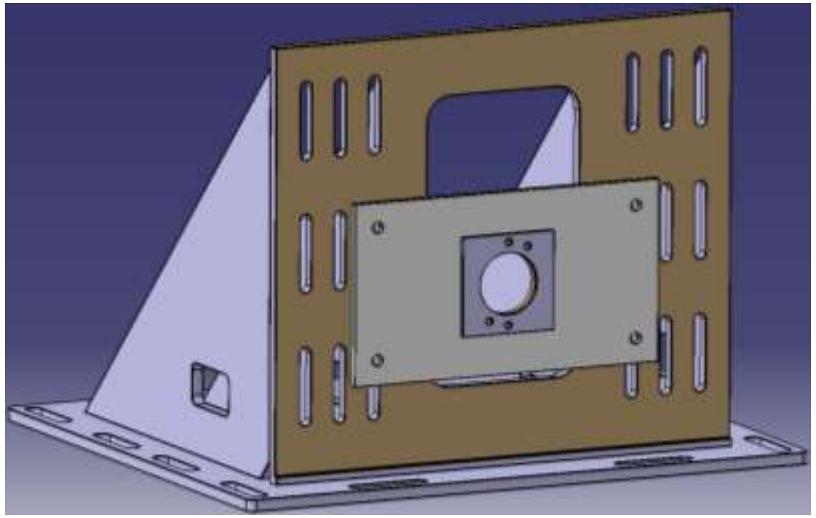
Gearbox Efficiency Improvement

A gearbox test bench at FH Joanneum will be used for the efficiency testing. A figure below shows the digital test bench setup. The main components (from left to right) are the asynchronous motor, the electromagnetic clutch, one bearing, the torque sensor, two servo couplings, the gearbox adapter, the connection flange for the gearbox input shaft and additional shafts. To temper the gearbox, a heater with a blower is available.



Test bench setup

Universal test bench adapter



Test Bench Configuration

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Gearbox Efficiency Improvement

The main function of the adapter is to ensure the correct mounting position of the gearbox on the test bench. Some important requirements for the adapter are: variable mounting orientations of the gearbox on the adapter without sacrificing its functionality, high rigidity, and simple assembly and production. To fix the gearbox on the adapter a Comex gearbox specific adapter plate is used as can be seen above.

To minimize the test runs, a DoE was developed as a test plan. With the DoE it is possible to find the best input parameter setting for the optimum output with minimum effort. It was possible to reduce the amount of possible tests down to one third.

Testing Procedure

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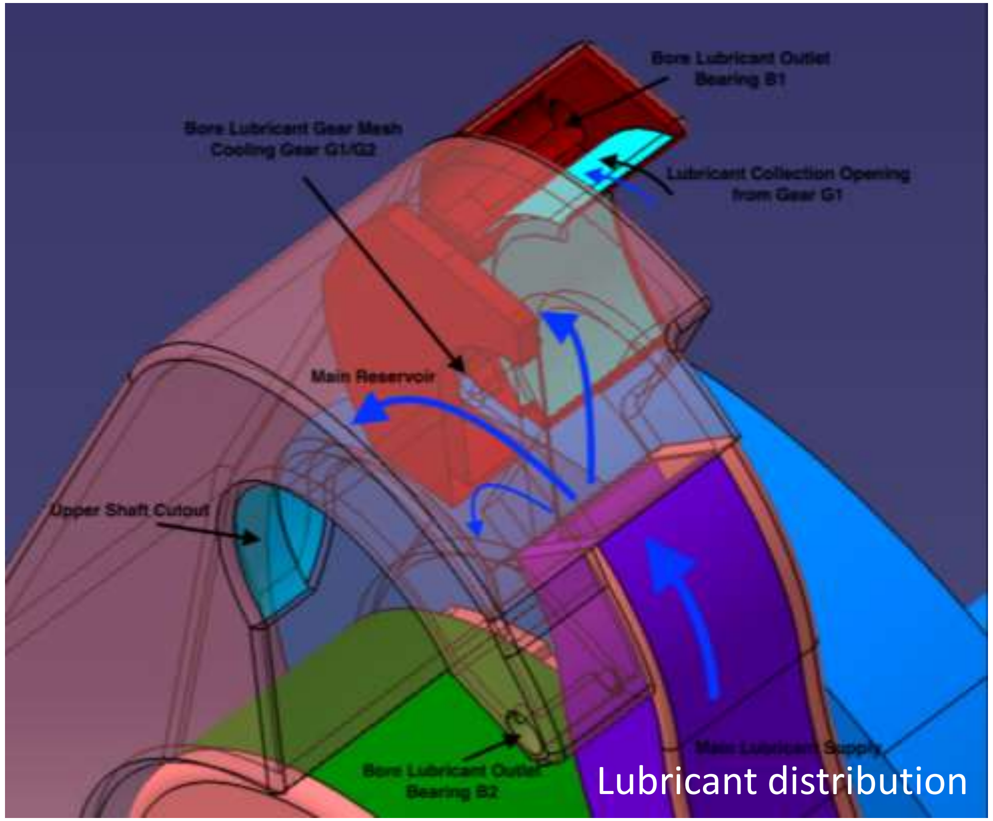
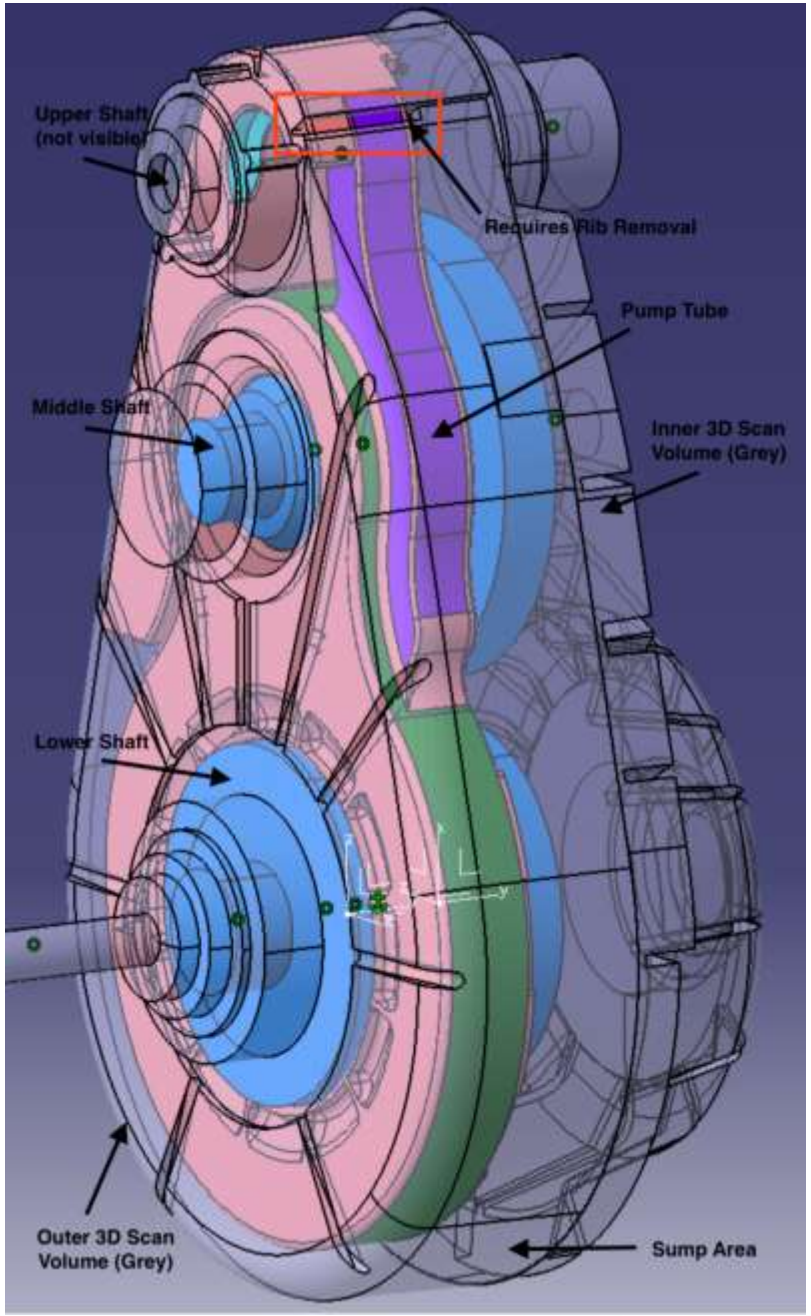
Gearbox Efficiency Improvement

A 3D scan of the existing gearbox housings interior was performed using a laser robotic arm. The scanned geometry was used to fit the polymer material parts precisely into the gearbox housing. A figure shows the CAD volume created off the 3D scan in grey. Additionally, the shafts (in dark blue) and the coloured polymer assembly are shown. A figure provides insights into the lubricant distribution after the gear pump elevates the lubricant.

Laser scan point cloud



Lubricant distribution



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Gearbox Efficiency Improvement

Prototype 3D printed lubrication improvement parts

- Production of the adapter and the improvement parts
- Test bench setup
- Testing based on the existing test plan (DOE)
- Testing results analysis

Outlook

Formula Student

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Formula Student

FORMULA SAE

DESIGNING

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Formula Student

Conceiving and designing

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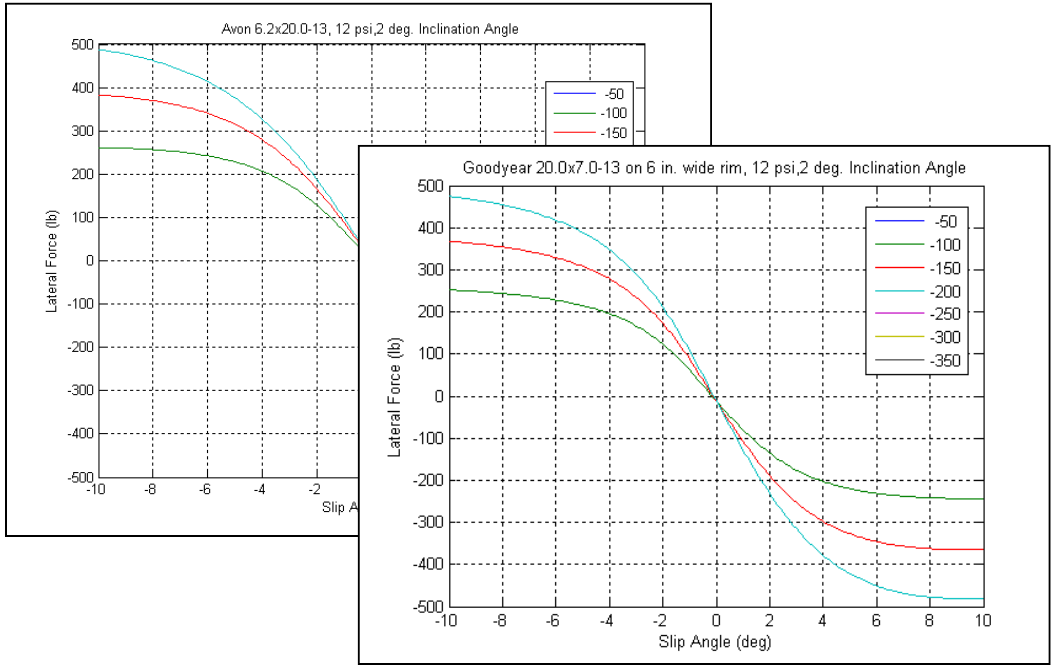
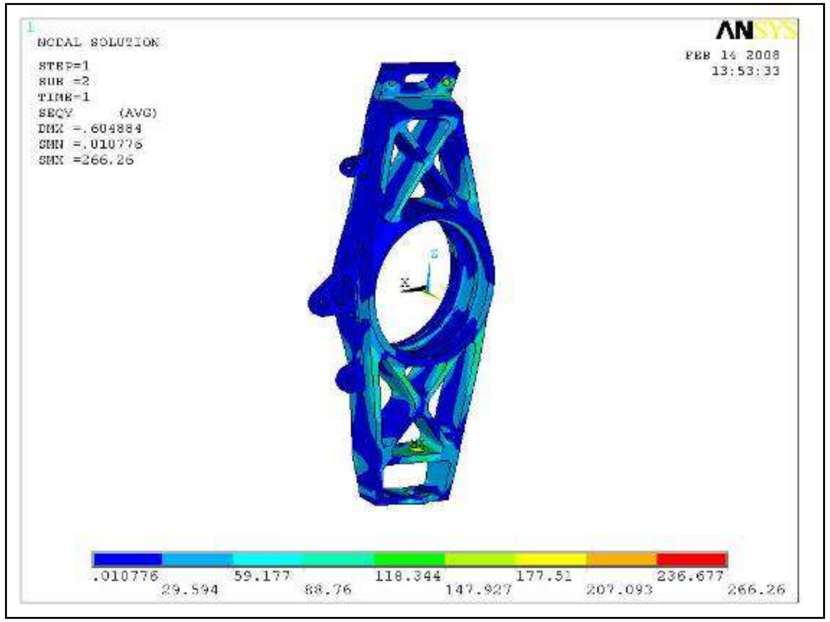
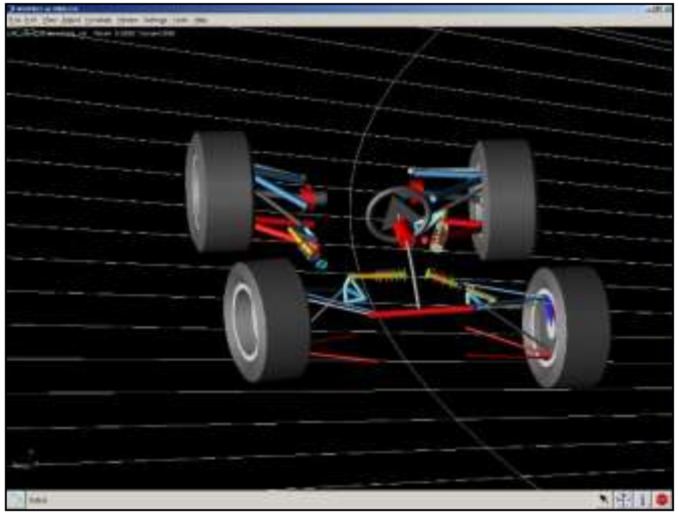
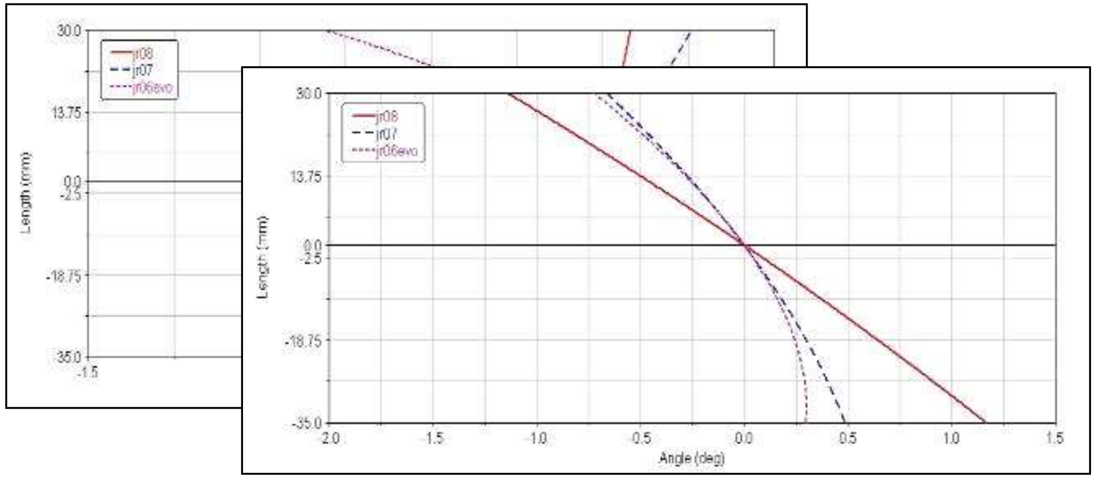
Formula Student









Calculation and simulation

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Manufacturing

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Assembly

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Assembly of vehicle

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Testing and development

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Competition

Static event
- Engineering design
- Business presentation
- Cost event

Dynamic event
- Acceleration
- Skid pad
- Autocross
- Endurance

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Workshop

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Engine calibration

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Preparation for static competition with lecturers

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Conceptual discussions with alumni

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Formula Student

Integration in curriculum:

- Bachelor theses
- Master theses
- Design exercises: Bachelor’s, Master’s
- Project Work
- English Foundation: Poster presentation of sub projects and internships

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Formula Student

Advantages for students and faculty:

- International comparison
- Part of a prospering community
- Development of entire(!) vehicle
- Areas of interest of vehicle engineer:
    - Design
    - Calculation/simulation
    - Manufacturing(assembly/quality assurance
    - Testing
    - Reporting and presenting
    - Sales and distribution
    - R&D
- Interdisciplinary activities
- Team work, dead lines, costs → entrance card to job
- Contacts to industry, risk-free career entry

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Drivetrain Efficiency

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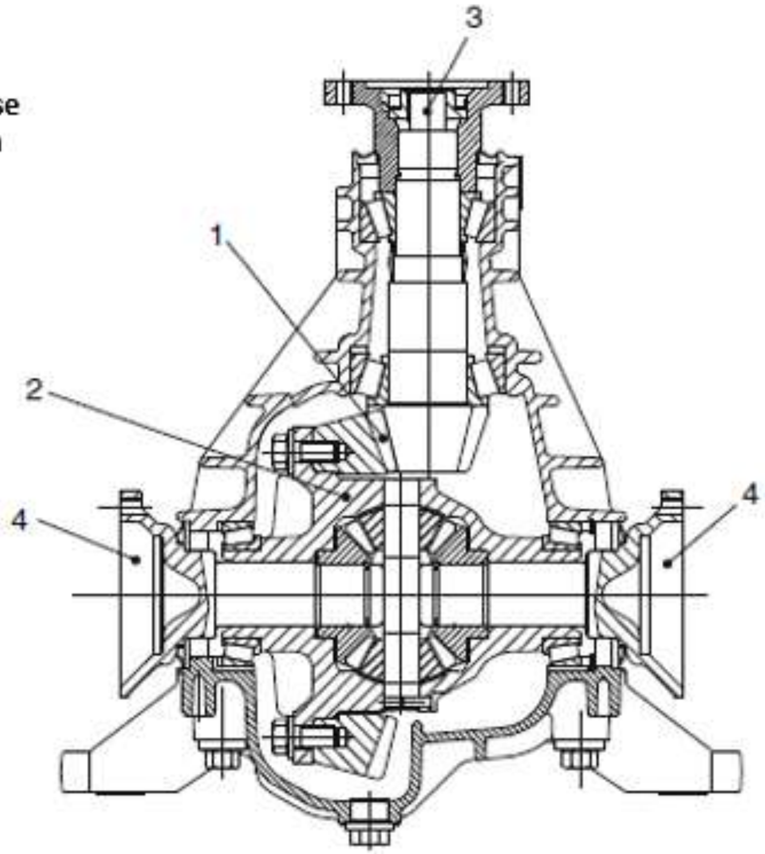
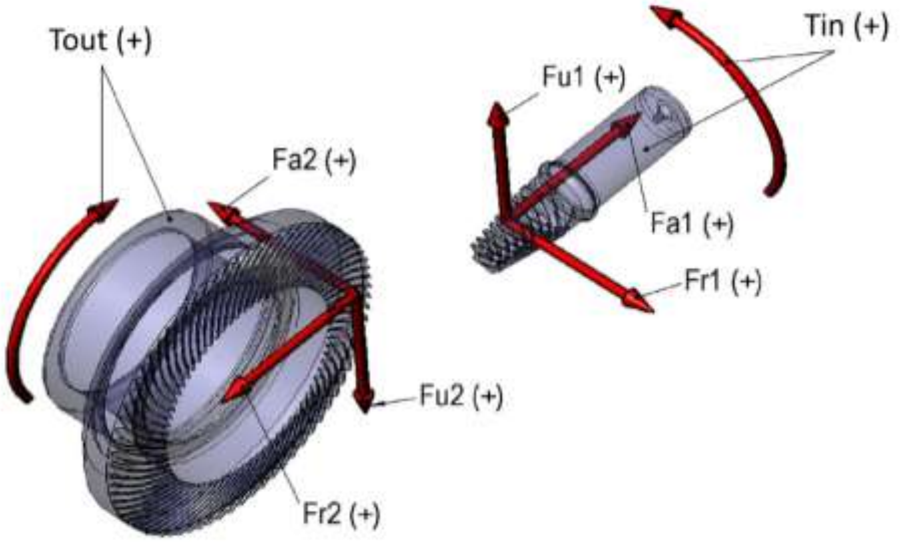
Drivetrain Efficiency

The aim of this project is the **investigation of a rear drive module (RDM)**, more precisely the drive shaft and the identification of its losses. Therefore a **literature study** concerning preloaded taper roller bearings and hypoid gearings is carried out. Based on that, the **relation between input torque and gearing forces** is worked out to use them for further calculations. To predict the influence of these gearing forces in combination with different operating temperatures and preloads, a **finite elements (FE) model** of the shaft bearing situation is set up.
With the help of a suitable calculation model for the losses within the bearings and the shaft seal, the **prediction of the frictional torque** is done. This model is implemented in **Matlab** to determine **the losses during a given drive cycle.**

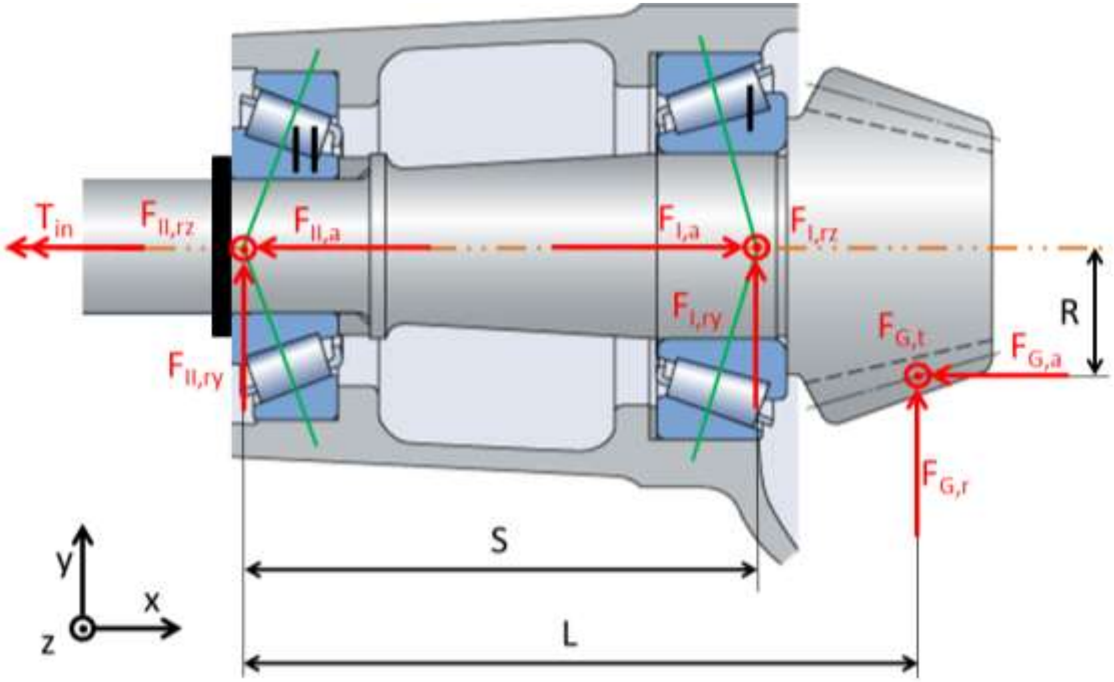


Objectives

Drivetrain Efficiency



The forces in the hypoid gearing depend on the geometry as well as on the transmitted torque. They are affected by the mean diameter d, the normal pressure angle α, the spiral angle β and the reference cone angle δ. The index 1 stands for the drive shaft and 2 for the ring gear.



To find the radial bearing forces in dependency of the gearing forces, the **equilibrium conditions** are set up. The forces on the bearings are applied on the supporting points. Their distance is the **supporting distance S**.

Gearing forces

Radial bearing forces

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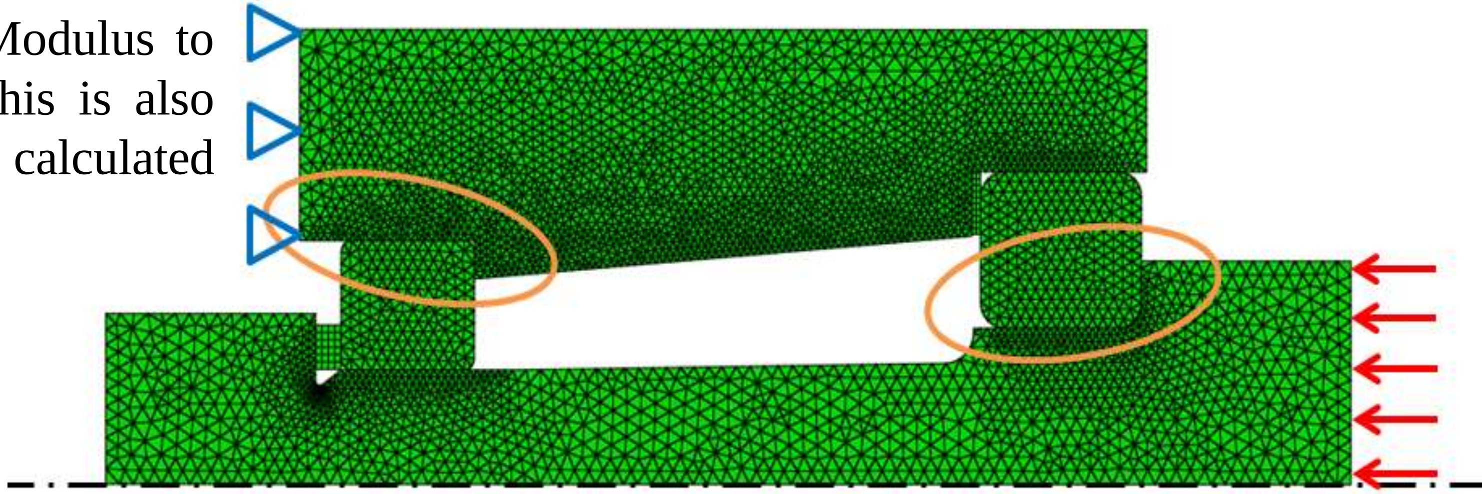
Drivetrain Efficiency

The shaft bearing consists out of to **preloaded taper roller bearings**. The main advantage is the higher axial stiffness with two relatively small bearings. Due to this preload, the system is **statically over-determined** and the compliances of the parts are needed for calculation.

To find the axial bearing forces, an **axisymmetric FE model** in Abaqus is set up. Therefore simplified models of the bearings and the housing are made. The stiffness of the **simplified bearings** is adapted via the Young's Modulus to reach the given stiffness data of the bearings. This is also carried out for the housing, where the stiffness is calculated out of the deformation due to an applied force.

The final axisymmetric model evaluates the **axial bearing forces out** of the **contact definitions**. The **preload** due to the oversized adjustment disc is applied via a **temperature difference**. This allows to simulate an operating temperature of the RDM. In a further calculation step the **axial gearing force** is applied on the right end of the shaft.



Model in Abaqus

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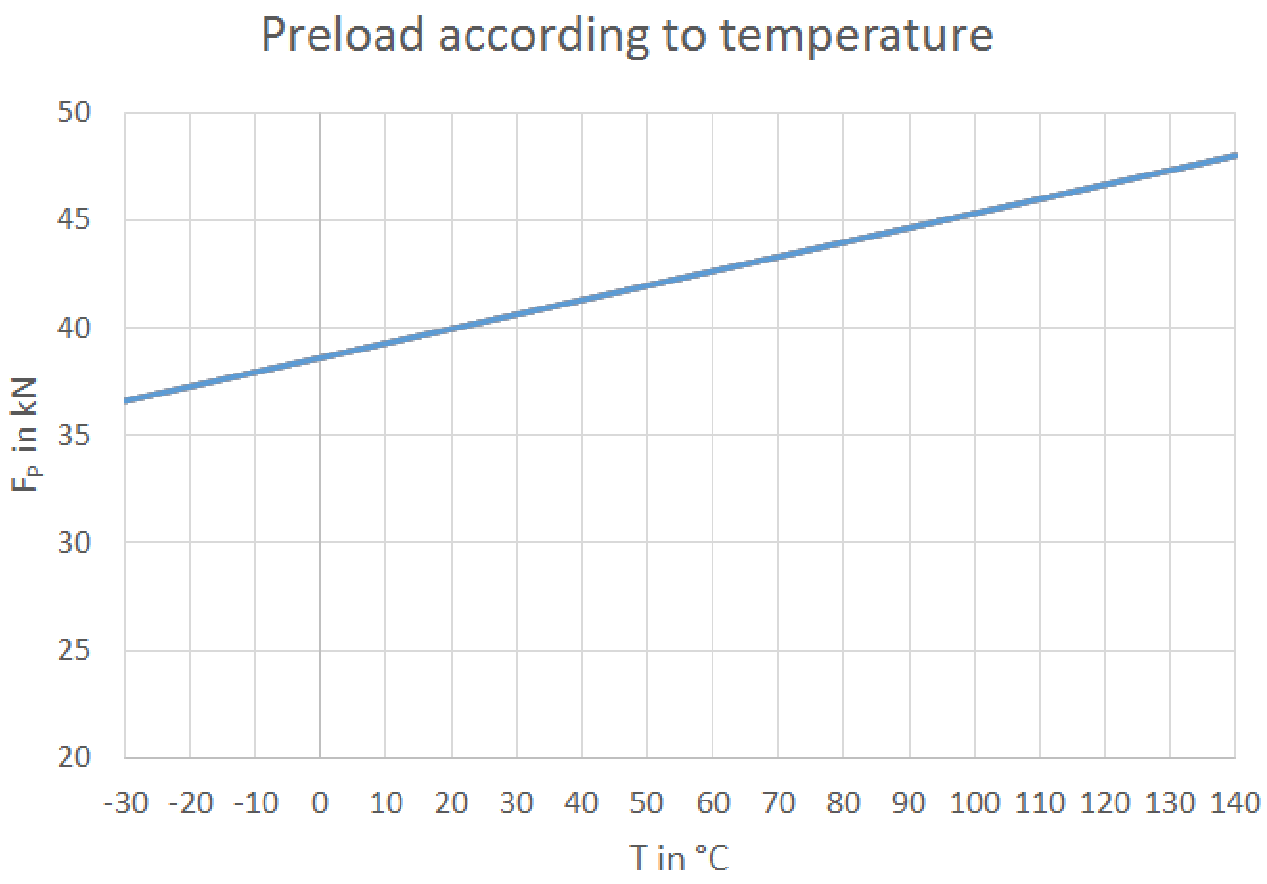
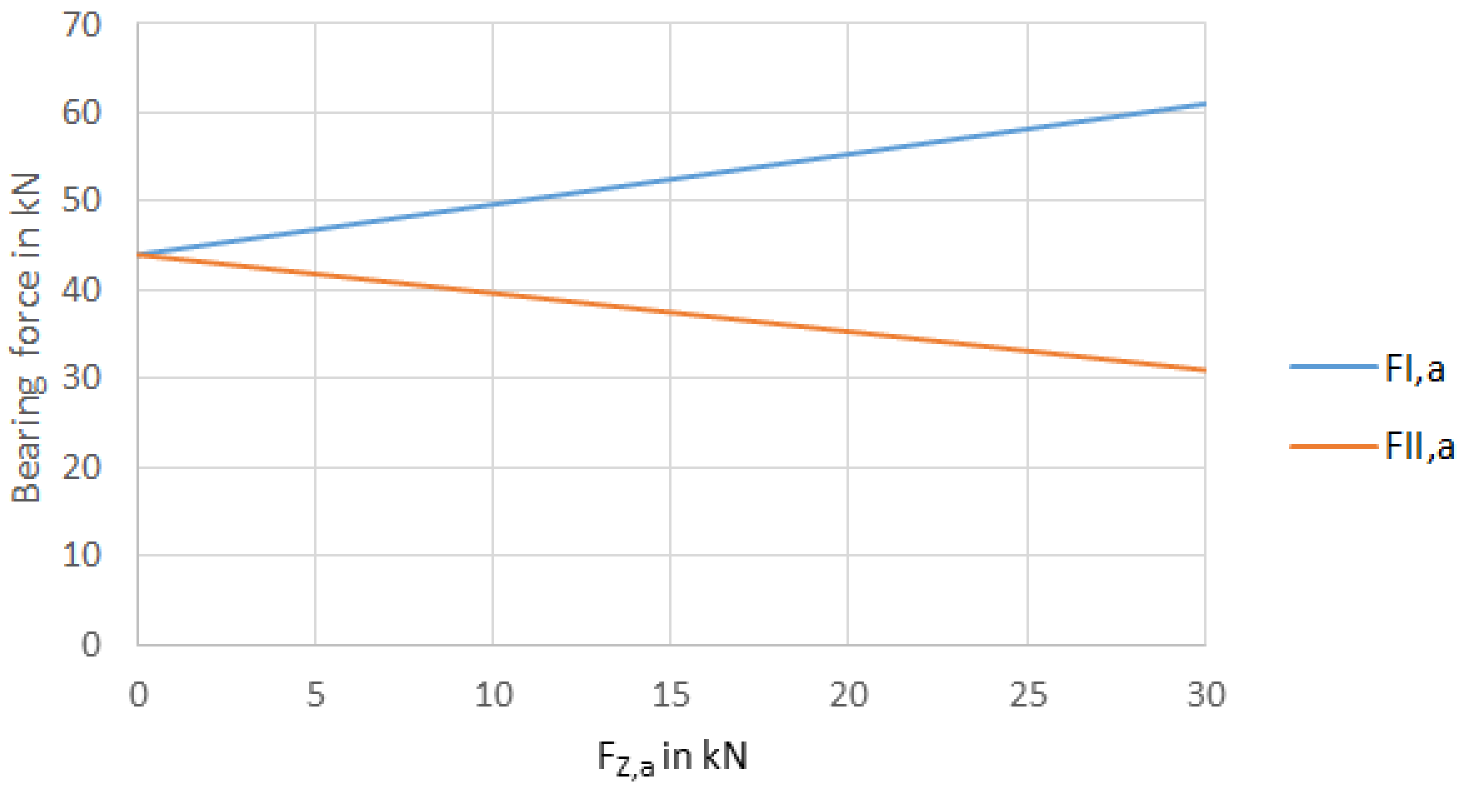
Drivetrain Efficiency



The first result of the calculation is the **influence of the temperature** to the preload, which is shown in the graph below.

Results

Drivetrain Efficiency



The second result shows the **bearing forces according to preload and axial gearing force**. The inner bearing load increases whereas the outer bearing load decreases with higher axial load.

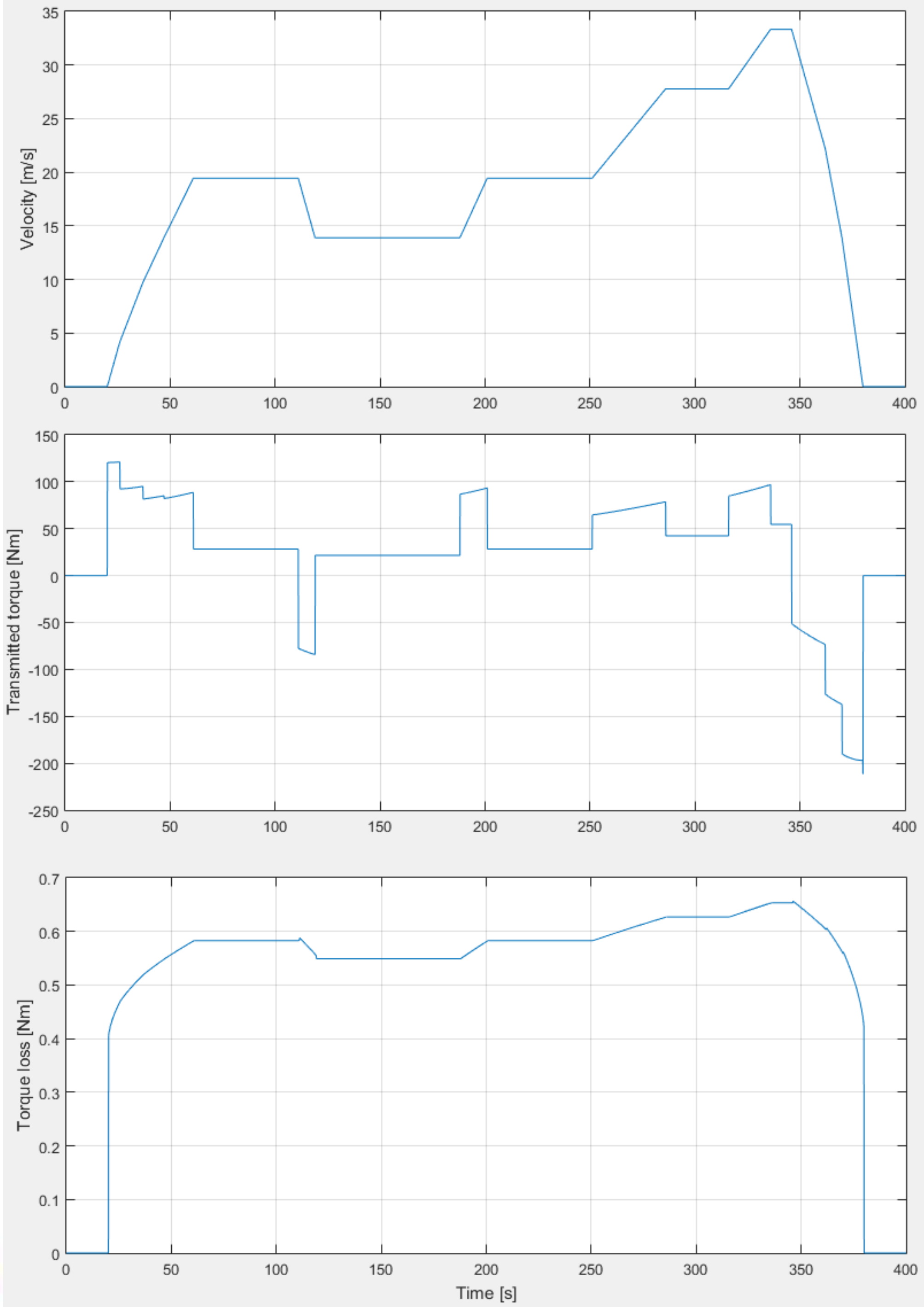
Results

Drivetrain Efficiency

To calculate the losses in the bearings of the drive shaft, it is necessary to find a relation between the loads on the bearings and the **frictional torque**. The bearings in the investigated rear drive module are therefore investigated in terms of their behaviour concerning loads in **radial direction** and in **axial direction**.

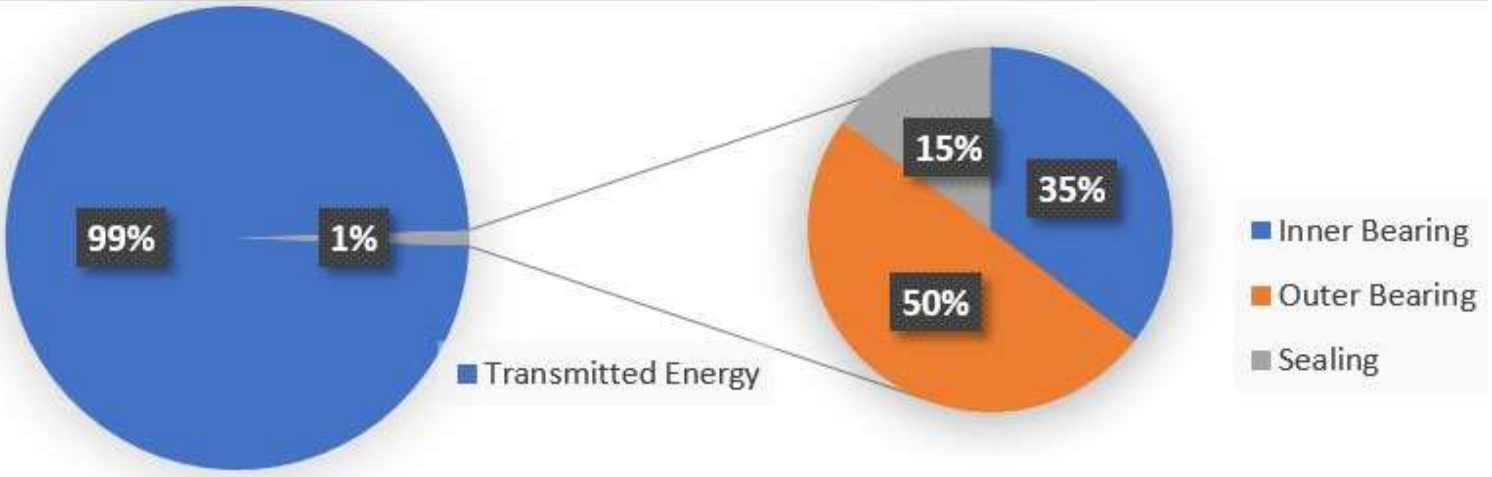
The total frictional torque created in bearings is made up by four parts: R**olling, sliding and seal friction** in the bearing and the torque due to the **displacement and churning** of the lubricant.

Frictional torque



Drivetrain Efficiency

The gained knowledge about calculating the **frictional torque** is implemented in **Matlab**. The drivetrain model is carried out for a vehicle with common dimensions and an **electric propulsion system**. This system is able to use the **braking energy for loading the accumulator**. This means that every frictional torque within the input shaft is seen as loss.
The graphs show the velocity, the transmitted torque and the torque loss during the **EUDC**.



Model in Matlab

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References

- • Reisinger K. et al.: Endbericht Innovationsscheck Plus 2017, FH Joanneum – AMSD, Mar. 2019. (*Final report of cooperation project*)

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Examples of Projects

4th Training in Rio de Janeiro, BRA

6th-9th of May 2019

Michael Trzesniowski, Thomas Lechner

Co-funded by the Erasmus+ Programme of the European Union