Test Design of the artificial damage tests for the PhD thesis of Yanik Koch – Institute of Product Development and Machine Elements of the Technical University of Darmstadt

Test bench at pmd TU Darmstadt:

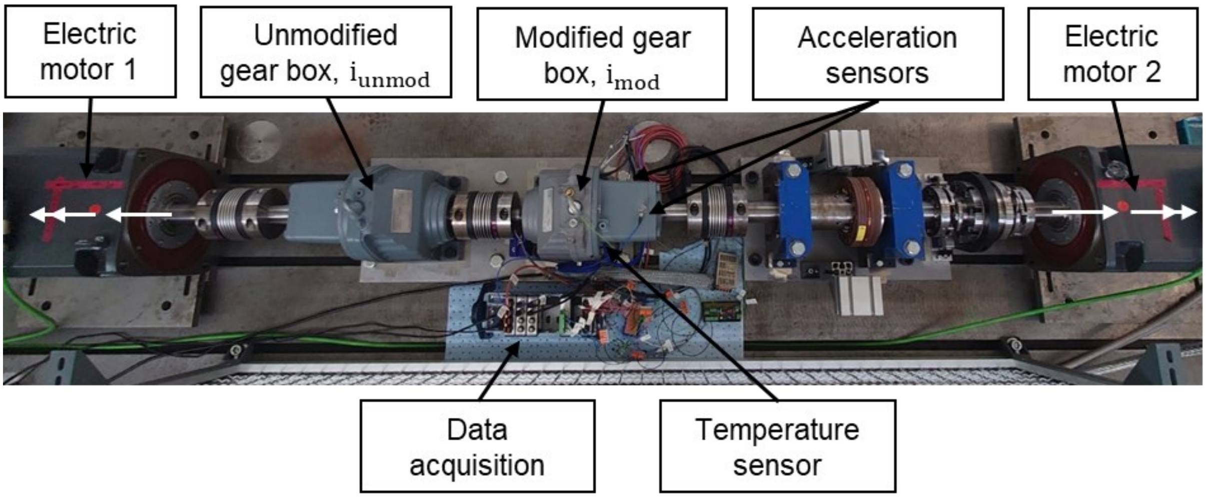
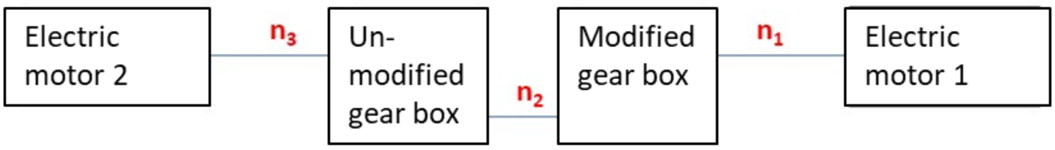


Figure 1: Test bench at pmd TU Darmstadt

- Electric motor 1 is speed controlled
- Electric motor 2 is torque controlled
- The speed and torque direction is defined as shown in Figure 1.
- The gear boxes are RX77/AD4 of SEW



Based on the number of teeth the gear ratio is calculated → $i_{unmod} = -\frac{21}{51} = -0{,}411$ $\quad i_{mod} = -\frac{78}{24} = -3{,}25$

Four quadrants oft the test bench:

Electric Motor 1 is speed controlled and Electric Motor 2 is torque controlled

- Q1: Electric Motor 1 negative speed, Electric Motor 2 positive torque
- Q2: Electric Motor 1 negative speed, Electric Motor 2 negative torque
- Q3: Electric Motor 1 positive speed, Electric Motor 2 negative torque
- Q4: Electric Motor 1 positive speed, Electric Motor 2 positive torque

Sensor integration:

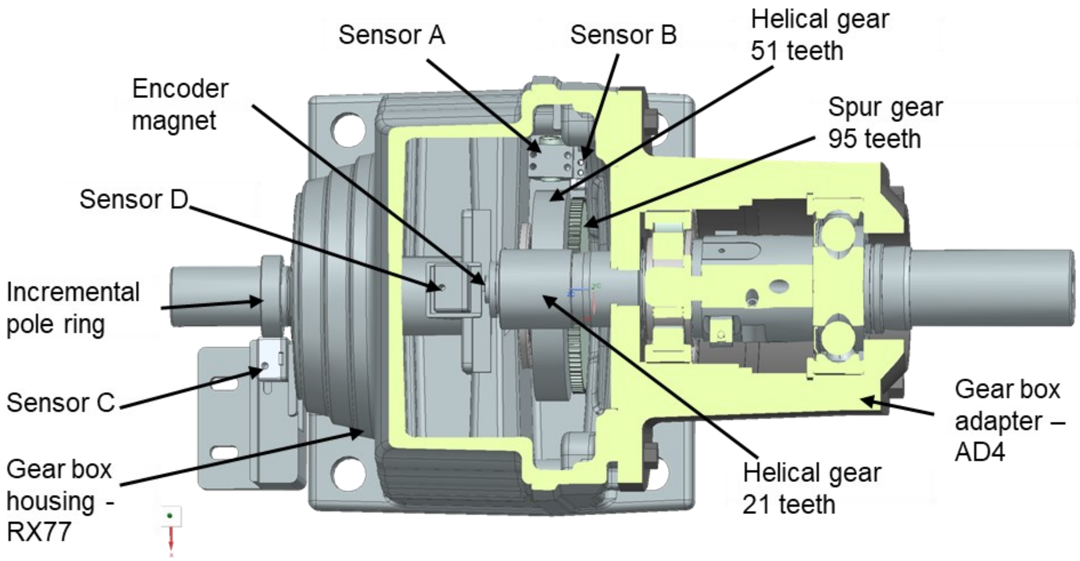


Figure 1: Integration of Magneotresisitive sensors CAD-illustration

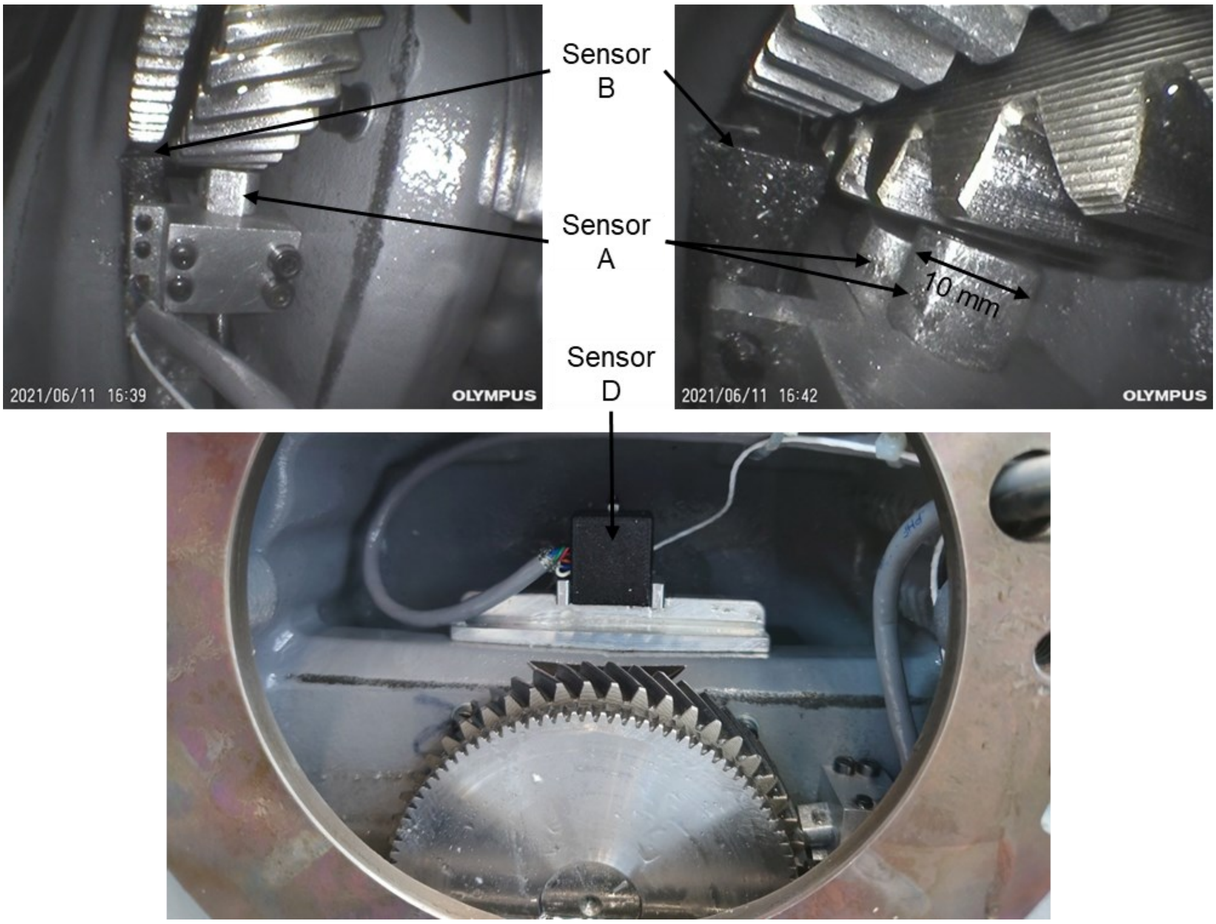


Figure 2: Integration of the magnetoresistive sensors in the gear box

Table 1: Measuring Scale of the magnetoresistive sensors

Sensor	Measuring scale
A	Helical gear wheel, $z_3 = $ **51 teeth**
B	Spur gear, $z_2 = $ **95 teeth**
C	Incremental pole ring, $z_1 = $ **256 poles**
D	Encoder magnet with north and south pole

Data acquisition

Table 2: sampling frequency of the NI-DAQ System

Chassis	Analog signals (Sensors B, C, D)	Analog signals (Sensor A)	Digital signals (Sensors C and D)	Acceleration sensors	Temperature Sensor (PT1000)
NI cDAQ 9178	NI9205 40kHz per Input	NI9215 100kHz per Input	NI9401 1MHz per Input	NI9234 51,2 kHz per Input	NI9215

Data preprocessing

The raw analogue signals are published. The sensors B, C and D generate a sine and cosine signal by design. Sensor A generates one sine signal, to generate a shifted signal two sensors are integrated and the upper one is shifted at 7/4 pitch.

Damages

Damages are artificially milled to the tooth flank. Damages are wrong adjust them!!!!

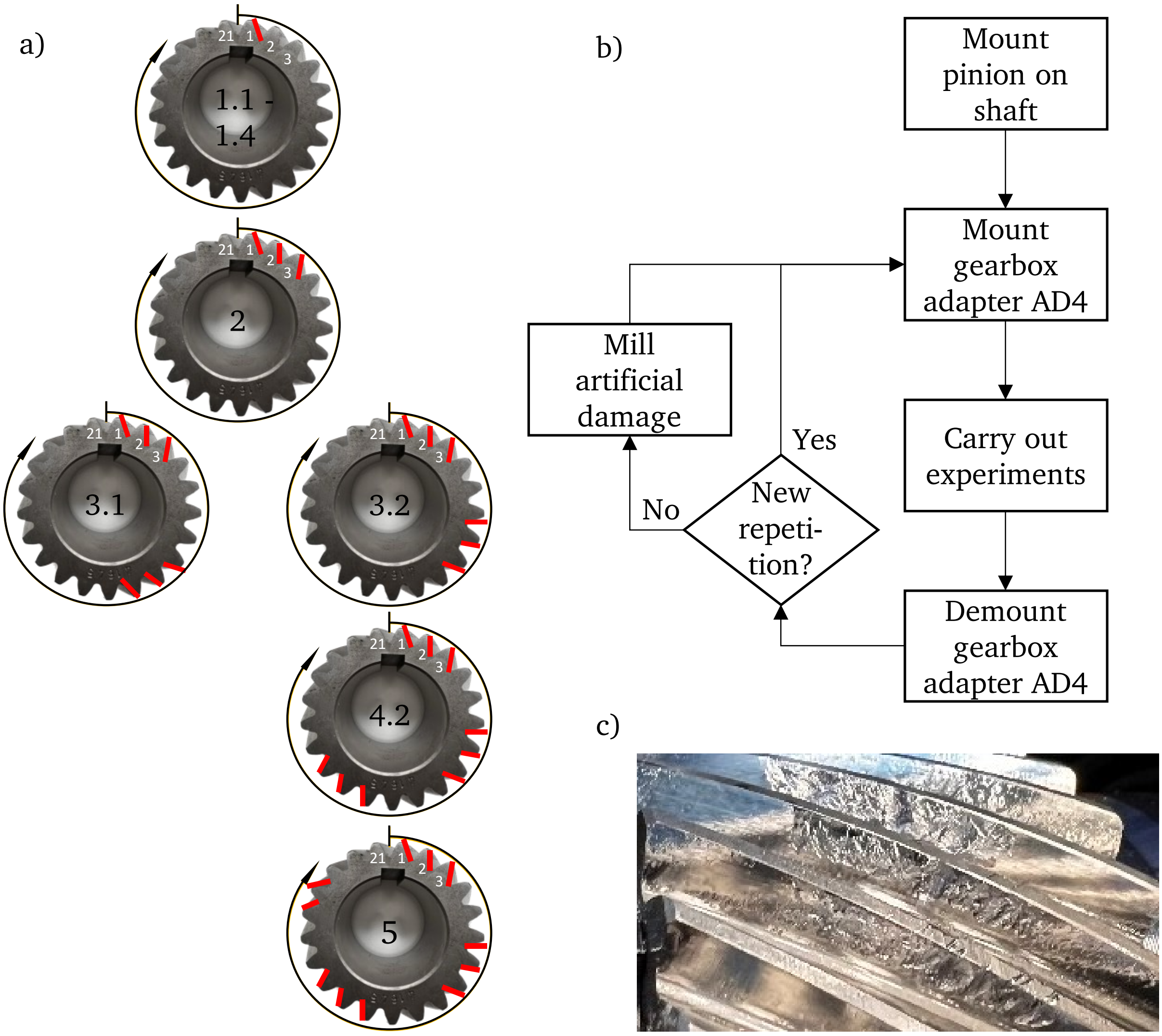


Figure 3: a) Explanation of damage conditions Picture of the artificially damaged gear. Damages as described in table 3.

Test design

Table 3: Operating conditions

	MT Marten Schäffner	BT Pablo de Orte
Description	Repeatability tests Pinions 2 and 3	Extension of test data Pinions 5 and 6
Torque in Nm	20, 55, 85	
Speed in rpm	300, 1300, 2000	
Number of operating conditions	$3(\text{speeds}) \cdot 3(\text{torques}) \cdot 4(\text{quadrants}) = 36$	
Damages & Description	0) No damage 1.4) Pinion 2 and 3: Grooves along one tooth flank	0) No damage 1.4) Grooves along one tooth flank 2) Grooves along the tooth flank of three adjacent teeth

	2) Pinion 2 and 3: Grooves along the tooth flank of three adjacent teeth 3.1) Pinion 1-3: Damage 3 additionally milled at teeth 120° rotated.	3.2) Damage 3 90° rotated 4.2) Damage 3 with two adjacent teeth damaged at 180° rotated 5) Damage 3 with two adjacent teeth damaged at 270° rotated
Recording time	5 s	5 s
Number of test conditions	$36\ \mathrm{OCs} \cdot 3(\mathrm{repetitions}) \cdot 4(\mathrm{fault\ conditions} \cdot 2(\mathrm{pinions}) = 864$	$36\ OCs \cdot 6(\mathrm{fault\ conditions}) \cdot 2(\mathrm{repetitions}) \cdot 2(\mathrm{pinions}) = 864$

Data naming:

The data is named based on the test parameters shown in table 3. Every test combination of speed, torque and damage condition has its own data set containing the previously described sensor data. The data is named as follows: “DamageW_QuadrantX_TrqYNm_RevZrpm”. “W” is the damage condition, “X” is the Quadrant, “Y” is the torque in Nm and “Z” is the speed in $\frac{1}{\mathrm{min}}$.