THE BRAZILIAN GEAR CONFERENCE 2021

ITA - WZL



Aeronautics Institute of Technology,
Competence Center in
Manufacturing

RWTH Aachen University (Germany),
Laboratory for Machine Tools and
Production Engineering

EIGENDAUER

VAS TECNOLOGIA INDUSTRIAL

KISSsoft Drivetrain Design Solutions

ESTUDIO PIÑA

SEW EURODRIVE BRASIL

KAPP NILES

RÖSLER finding a better way...

OTEC PRECISION FINISH

Bruker alicona That's metrology!

Mitutoyo Sul Americana

HBK HOTTINGER BRÜEL & KJÆR

LIEBHERR

oerlikon balzers

Höganäs

CNPq Conselho Nacional de Desenvolvimento Científico e Tecnológico

Investigations on Gear Perfomance for e-Mobility Applications – *Carlos Beraldo (Suspensys) / Tiago Colombo (ITA)*

Electric mobility combines higher torque and speed operational ranges, thus leading to an explicit impact especially on the gears of the transmission system. Higher rotation speeds come accompanied by an increased number of cycles and a higher thermal input when operating. Additionally, they also significantly change the gear excitation behavior, which, in the absence of a noisier internal combustion engine, brings attention to the emission of noise from the transmission gears. Therefore, new requirements are being established when designing gears for e-mobility, thus affecting both product and gear manufacturing solutions. New materials that provide higher mechanical strength and toughness, less dimensional variation in manufacturing and greater vibrational dissipation are examples of new technologies to be derived from this specific demand. Stronger concerns raise around the surface integrity of new alloys and how these properties are driven by the gear manufacturing chain. Within this aspect, this study aims to present approaches for investigating the surface integrity of new steels for application in gears for electric mobility. Different experimental methods for evaluating the durability of new materials when subjected to conditions that promote failures by contact fatigue and bending fatigue are presented. Implications of the manufacturing chain and experimental approaches to investigate its impacts are also considered. Testing procedures and equipment under development at ITA, especially for durability investigations, are discussed.

Investigations on Gear Performance for *e-Mobility* Applications

Carlos Eduardo Michelin Beraldo, M.Sc. *(Suspensys)*
Tiago Colombo, Dr. *(ITA)*

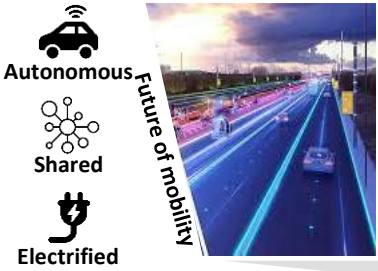
São José dos Campos, November 9th & 10th, 2021

Agenda

1. Introduction and Motivation
2. Assessing Gears for e-Trucks
3. Summary and Outlook

Introduction: *Worldwide e-Trucks trends*

- Gears for *e-Mobility*

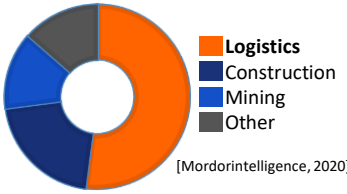


- e-Trucks market grow rate (2021-2026)



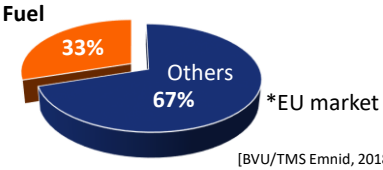
[Mordorintelligence, 2020]

- e-trucks market revenue (%)



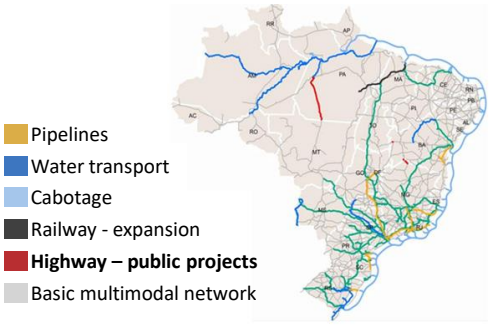
[Mordorintelligence, 2020]

- Costs for standard diesel tractor + semitrailer*

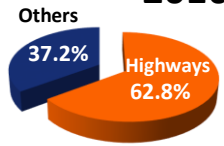


[BVU/TMS Emnid, 2018]

Introduction: *Brazilian modal share*



2016:

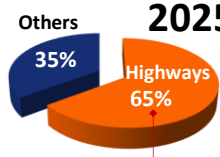


Projected highways share ***growth***

Model of implementation	Year 2009 km	2009 %	2019 km	2019 %	Variation 2009-2019
Planned	≈131.2k	7.7	≈157.3k	9.1	≈19.9 %
Not paved	≈1.4 mi	80	≈1.35 mi	78.5	≈1.3 %
Paved	≈212.5k	12.4	≈213.5k	12.4	≈ 0.5 %
Total extension	≈1.71 mi	≈100	≈1.72 mi	≈100	0.5 %

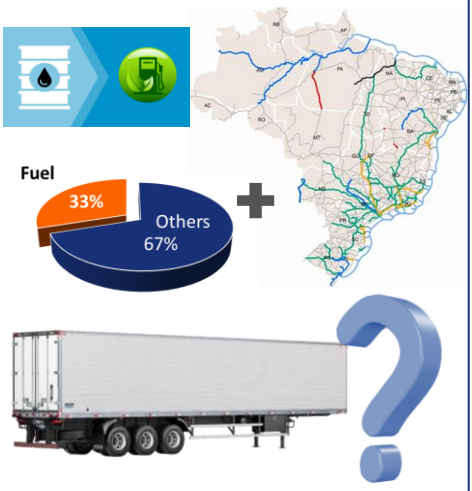
[EPL report, 2018]

2025:

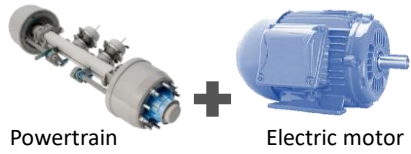


Introduction: *Randon e-Sys*

Challenges for commercial vehicle sector

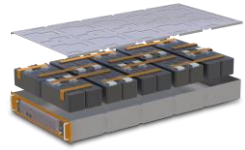


Ideation of e-Sys concept



Powertrain

Electric motor



Battery packs

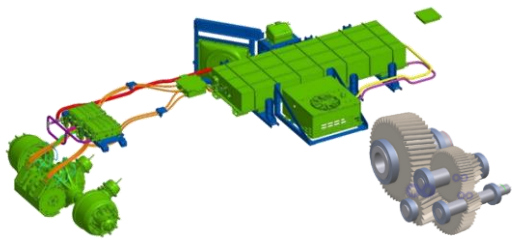
e-Sys

Up to 25% of **fuel economy**



Introduction: *Randon e-Sys*

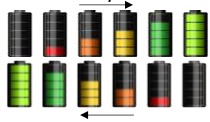
Performance



Traction + **Regeneration**



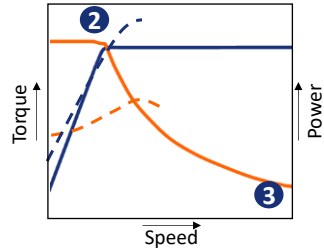
Battery level



1 **KERS**: kinetic energy recovery system

The Gear Box Challenge

ICE vs Electric Engines



Torque (electric) Power (electric)

Torque (ICE) Power (ICE)

e-Mobility demands:

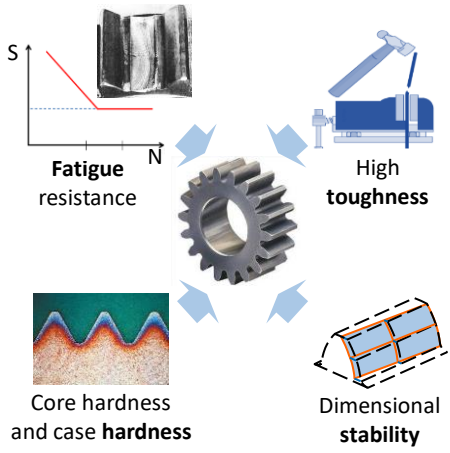
1 **Reverse** loading

2 **Steep** torque transient

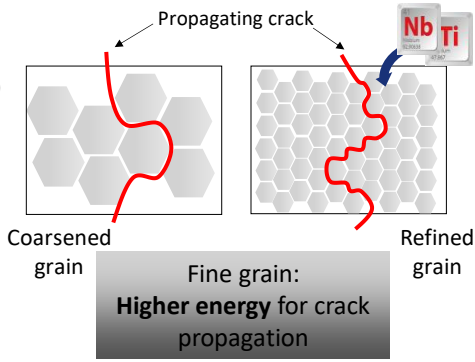
3 Higher **speeds**

Introduction: *Material and manufacturing challenges*

- Material requirements for *e-mobility* gears



- Niobium and titanium precipitates act as a **grain pinner:**
  - **Grain refinement** is the only way to **improve both** mechanical **strength** and **toughness**



Source: [MATL05; CBMM18]

Introduction: *Project overview*

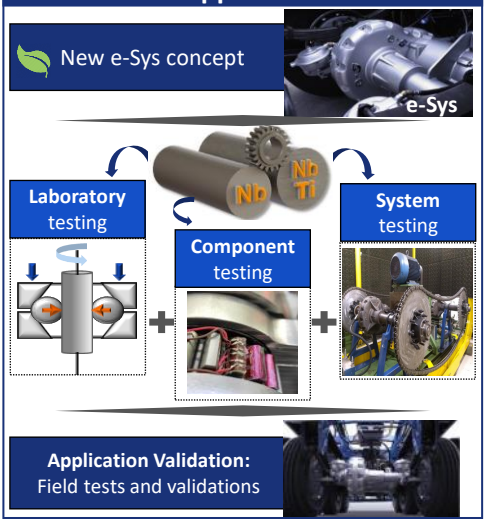
Objective

Mapping of the **mechanical performance** of **new steel alloys** designed for the **e-Sys gearing system** by analyzing the surface integrity induced by the manufacturing chain



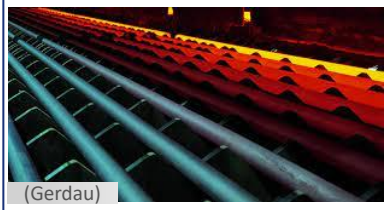
Partners

Approach

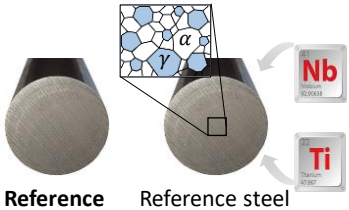


Introduction: *Project overview*

Investigations of new steels



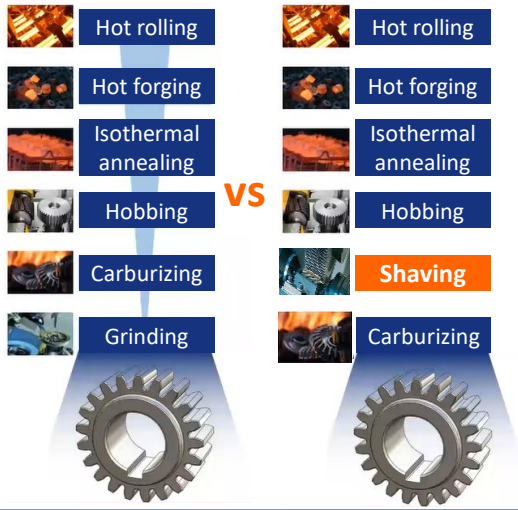
(Gerdau)



Reference steel

Reference steel with **enhanced** chemical **composition**

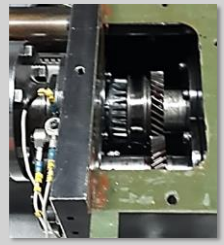
Investigations of manufacturing chain



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1. Introduction and Motivation
2. Assessing Gears for e-Trucks
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Assessing Gears for e-Trucks: *Testing stages*

APPLICATION VALIDATION	SYSTEM TESTING	COMPONENT TESTING	SIMPLIFIED INVESTIGATIONS
Vehicle	***Transmission***	***Gears***	***Laboratory Analogy***
			
[Suspensys]	[Suspensys]		

Application Representativeness

Testing Acceleration

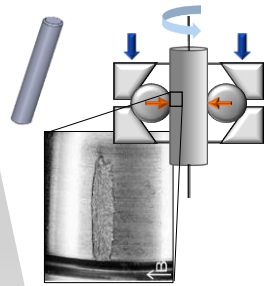
Assessing Gears for e-Trucks: *Rolling contact fatigue*

SIMPLIFIED INVESTIGATIONS

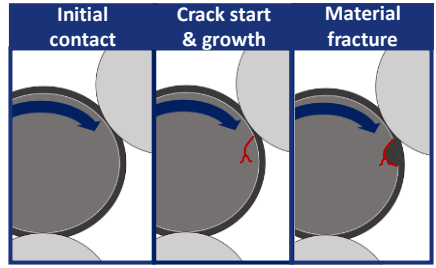
Lab analogy

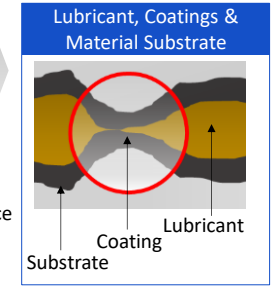


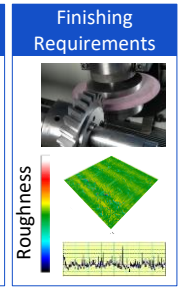
Ball-Rod Test Rig



- Addressing the *e-Mobility* **higher speed** demands:
  - **Lubricants**
  - **Coatings**
  - Alternative surface **finishing**







Assessing Gears for e-Trucks: *Rolling contact fatigue*

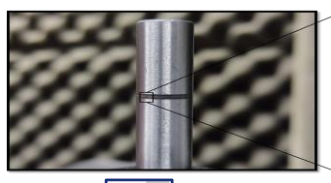
SIMPLIFIED INVESTIGATIONS

Lab analogy



Ball-Rod Test Rig

Preliminary results

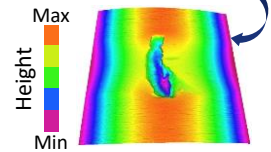


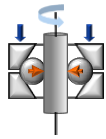


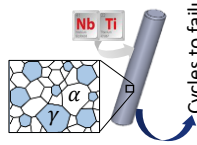


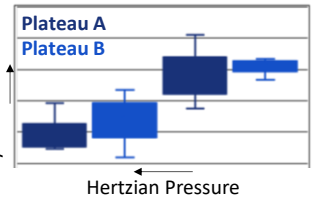


Crack propagation





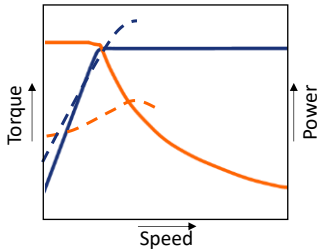




Assessing Gears for e-Trucks: *Rolling & Sliding contact fatigue*

The Gearbox Challenges

ICE vs Electric Engines



Torque (electric) — Power (electric)
Torque (ICE) — Power (ICE)

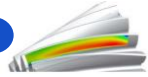
e-Mobility demands: 1

- **Reversal** loading
- **Steep** torque **transient**.
- Higher **speeds**.

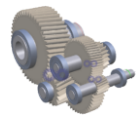
High Speed Twin Disk

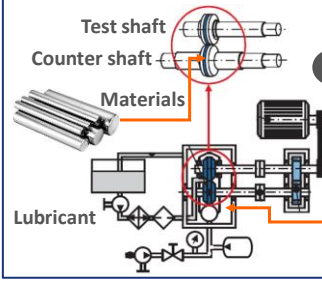
- ***e-Mobility*** demands **higher** rotational **speeds**.
- Gears contact fatigue tests require **high efforts** in **time and costs**.

1 *e-Mobility* demands + 2 3D Tooth Contact Analysis + 3 Hertzian Pressure



Contact Pressure
Min Max





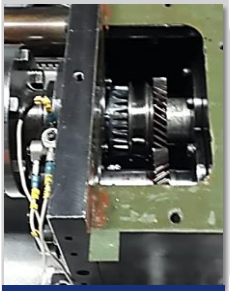
3 **High Speed Twin Disk**

[WZL]

Assessing Gears for e-Trucks: *Bending fatigue*

COMPONENT TESTING

Gears



Pulsator Test Rig

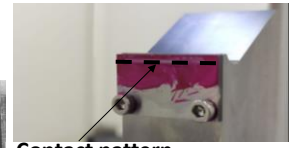
Tooth Root Stresses

- Pulsator rig:
  - **Cyclic load** applied in a single tooth
  - **Bending fatigue** failure induction

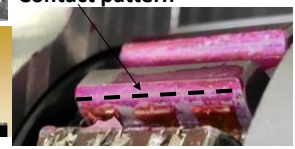
Root breakage



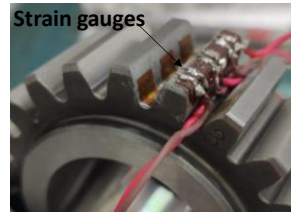




Contact pattern

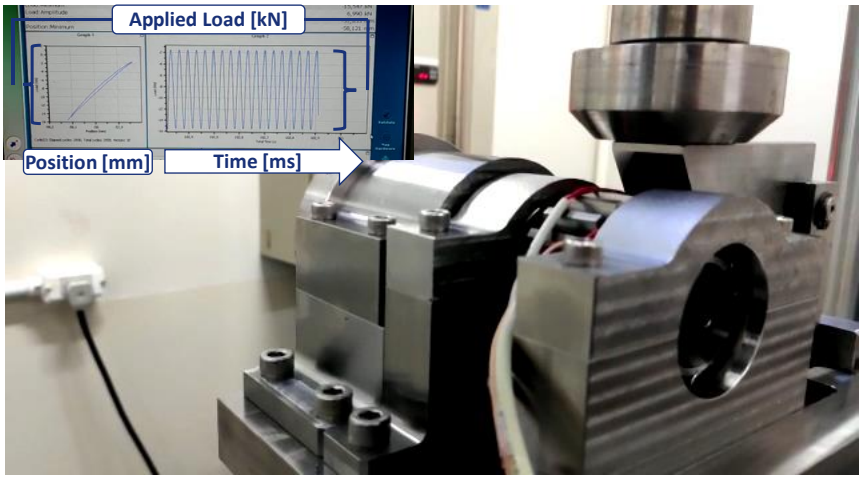


- Addressing the ***e-Mobility* demands**:
  - **Reverse** loading
  - **Steep** torque transient



Strain gauges

Assessing Gears for e-Trucks: *Bending fatigue*

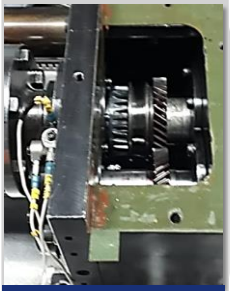


Assessing Gears for e-Trucks: *Full gear assessment*

- Contact fatigue tests

COMPONENT TESTING

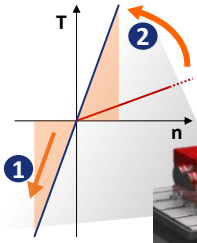
Gears



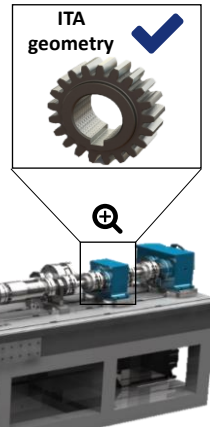
Power Circulating Gear Test Rig

e-Mobility demands:

1. **Reverse** loading
2. **Steep** torque **transient**



Power circulating gear test rig



Assessing Gears for e-Trucks: *e-Sys system testing*

SYSTEM TESTING

Transmission



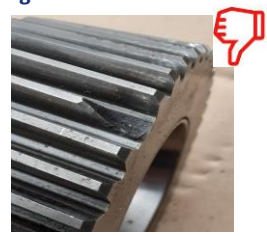
[Suspensys]

Four Square Test Rig

Four Square Test Rig



- Four square gear test rig designed by **Suspensys** exclusively for durability testing of ***e-Sys*** mechanical components.



1st test: original gear



2nd test: redesigned gear

Agenda

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Summary and Outlook

- *e-Mobility* Challlenges







Reverse Loading 1

2 **Steep** torque transient

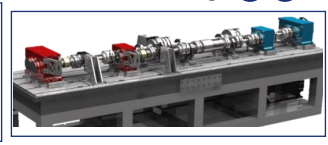
3 Higher **speeds**

- Experimental Approaches

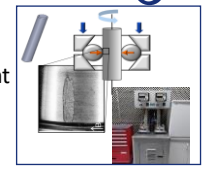
Pulsator 1 2



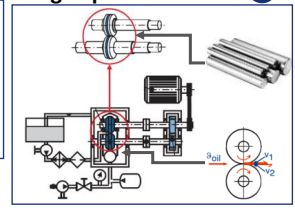
Power Circulating 1 2



Ball-Rod 3



High Speed Twin Disc 3





Four-square *e-Sys full testing* 1