Current activities for improved rotorcraft drivetrain safety and related research of TU Vienna with special focus on improved lubricants for rotorcraft transmissions

Prof. WEIGAND
TU Vienna

EASA European Union Aviation Safety Agency | Rotorcraft and VTOL Symposium 2021

Current activities for improved rotorcraft drivetrain safety and related research of TU Vienna with special focus on improved lubricants for rotorcraft transmissions

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European Rotors, Cologne, Nov. 17th, 2021

Improved rotorcraft drivetrain Safety and related research at TU Wien

Agenda

1. Transmissions for aviation at TU Wien
2. Integrity Improvement of MGB
3. Safety assessment & FMECA
4. Detection of abrasion & status monitoring
5. Freewheel operation
6. Lubricants & Loss of lubrication

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Classes / Courses 307 - 3 for Bachelor and Special Focus Design for Master										
Date: 27.11.2017										
Semester	BACHELOR 1	BACHELOR 2	BACHELOR 3	BACHELOR 4	BACHELOR 5	BACHELOR 6	MASTER 1	MASTER 2	MASTER 3	MASTER 4
	Techn. Drawings CAD	***Basics of Design***	**Machine Elements**	**Machine Elements KU in 4. or 5. Sem.**		**Bachelor Thesis**	**Machine Elements - Advanced -**	**Machine Elements - Advanced -**	**Machine Elements - Advanced -**	**Master Thesis**
	VU 2/307-1	*VO 2/307-1*	VO 3	UE 3 (KU)			VO 2	UE 4 (KU)	PA 4	
	307.426 (2)	*307.428 (3)*	307.451 (4)	307.453 / 307.452 (3)		307.418 (5/10)	307.454 (3)	307.455 (4)	307.482 (5)	(30)
		Techn. Drawings CAD		**Machine Elements** -Applications -					**Transmissions Selected Chapters**	**Transmissions Selected Chapters**
		UE 3/307-1		VU 2					UE 5	VO 2
		307.427 (3)		307.448 (3)					307.474 (5)	307.473 (3)
				Machine Elements - Applications - RU in 4. or 5. Semester				**Trans-missions for Aviation**	**Trans-missions for Aviation**	**Tribology of Machine Elements**
				UE 2 (RU)				VO 2	SE 2	VO 2
				307.449 (2)				307.459 (3)	307.461 (3)	307.483 (3)
	Research Unit Machine Elements and Transmissions for Aviation			**Methods of 3D - CAD**				**Trans-missions for Aviation**	**Trans-missions for Aviation**	**Lubricated Contacts**
				VU 2/307-5				UE 3 (LU)	PA 4	VO 2
				307.450 (2)				307.460 (3)	307.085 (5)	307.485 (3)
								Special Maschine Elements	**Special Maschine Elements**	
	ECTS credits are shown in brackets							VO 2	UE 4 (KU)	
								307.456 (3)	307.457 (4)	
Semester	BACHELOR 1	BACHELOR 2	BACHELOR 3	BACHELOR 4	BACHELOR 5	BACHELOR 6	MASTER 1	MASTER 2	MASTER 3	MASTER 4

- **Special Courses about Transmissions for Aviation**
- **Professorship for Tribology (Prof. Gachot) since 2016**
- **Professorship for Aircraft Systems (Prof. Berens) since 2021**
- **Master course „Aeronautics“**

FVA
Forschungsvereinigung Antriebstechnik e.V.

Deutsche Gesellschaft für Luft- und Raumfahrt Lilienthal-Oberth e.V.

AIRMED PRAHA 2008

American Gear Manufacturers Association

AHS INTERNATIONAL
THE VERTICAL FLIGHT SOCIETY

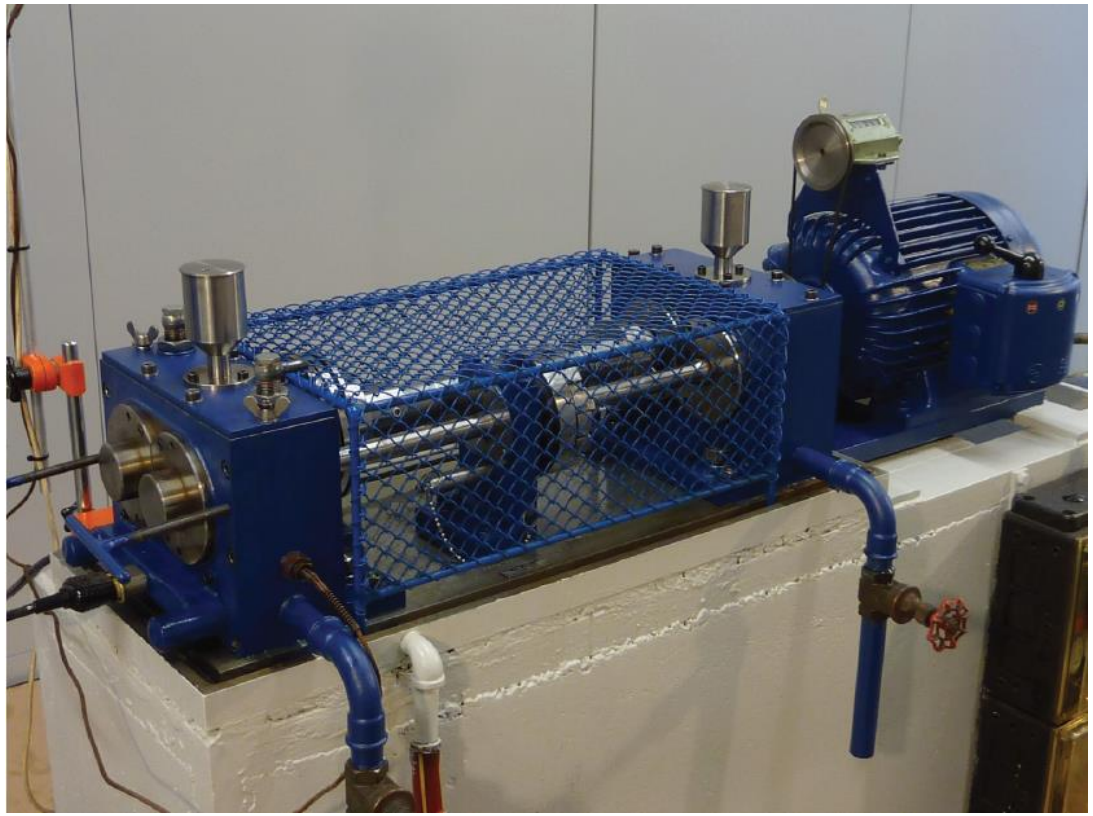
AIR MED 24-27 MAY WORLD CONGRESS BRIGHTON 2011

TU WIEN VGR Vienna Gear²ing

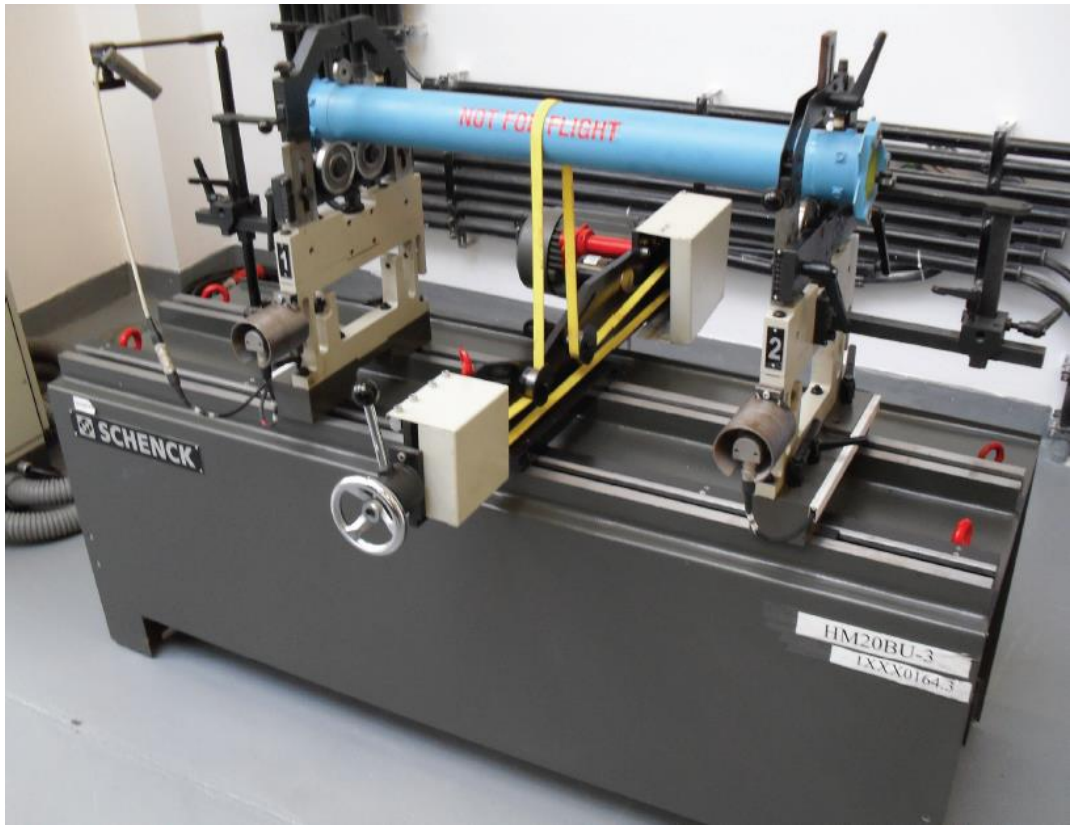
IFAR INTERNATIONAL FORUM FOR AVIATION RESEARCH

WiGeP

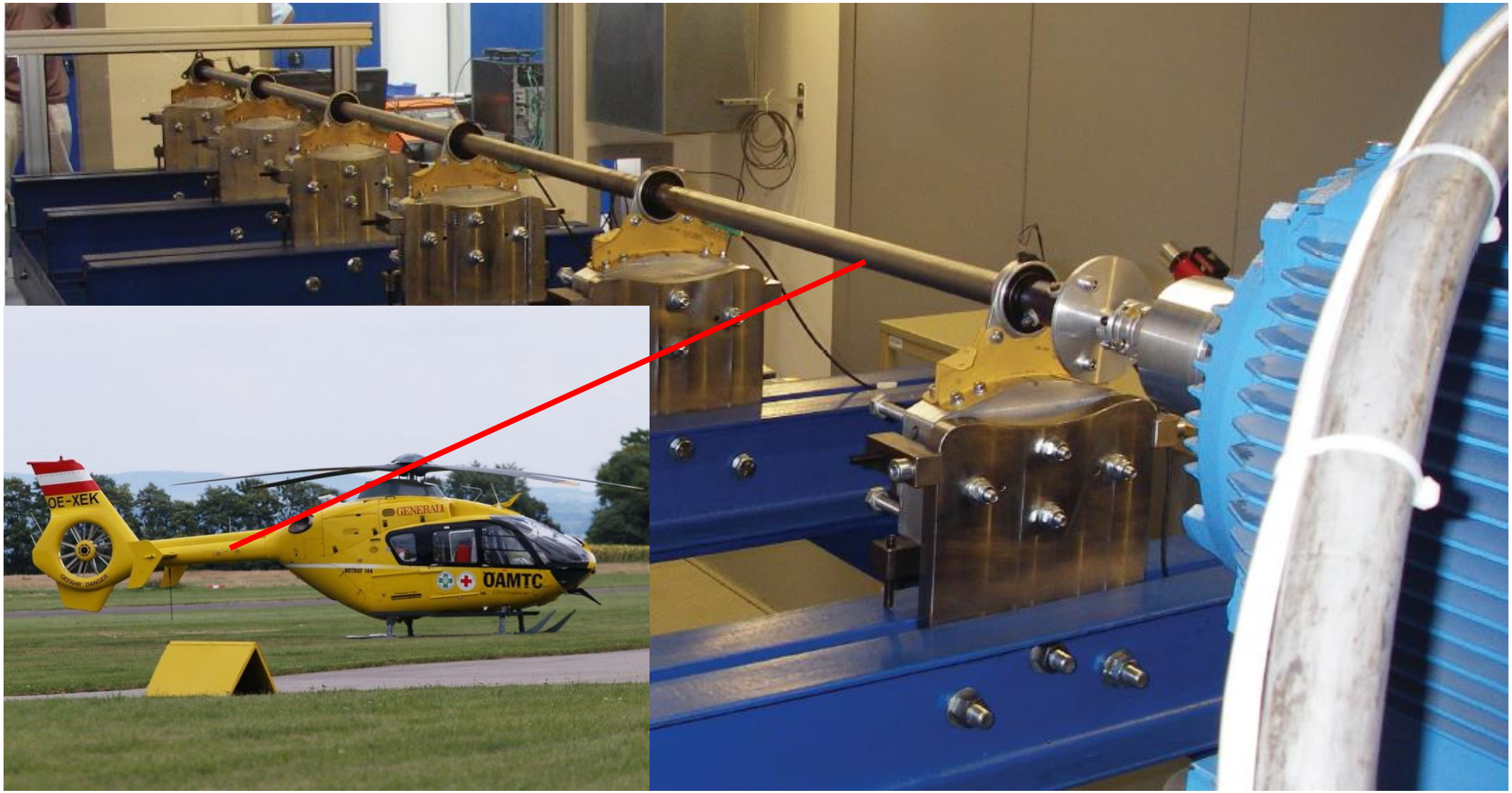
TU WIEN TECHNISCHE UNIVERSITÄT WIEN Vienna University of Technology

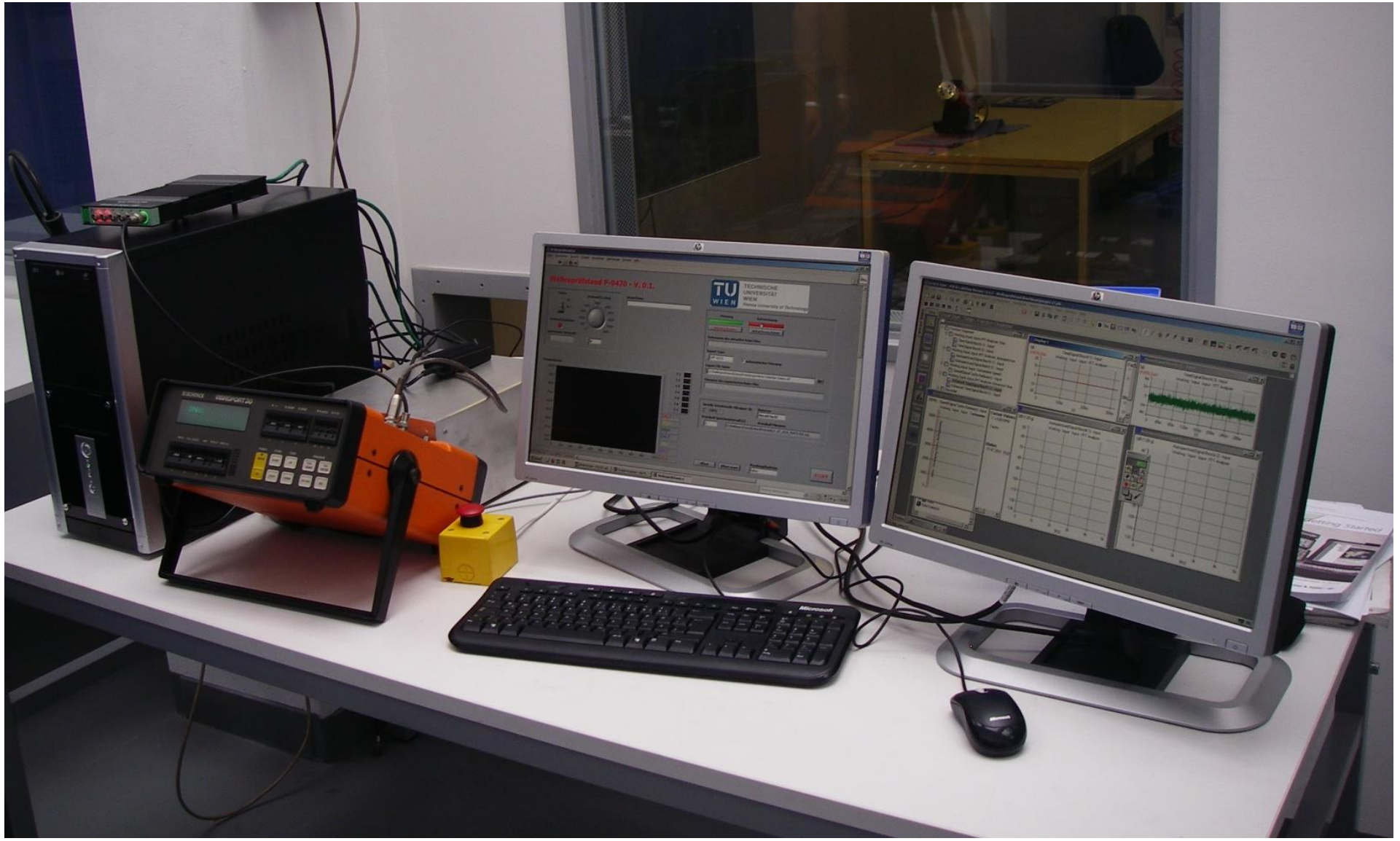


FZG Teststand

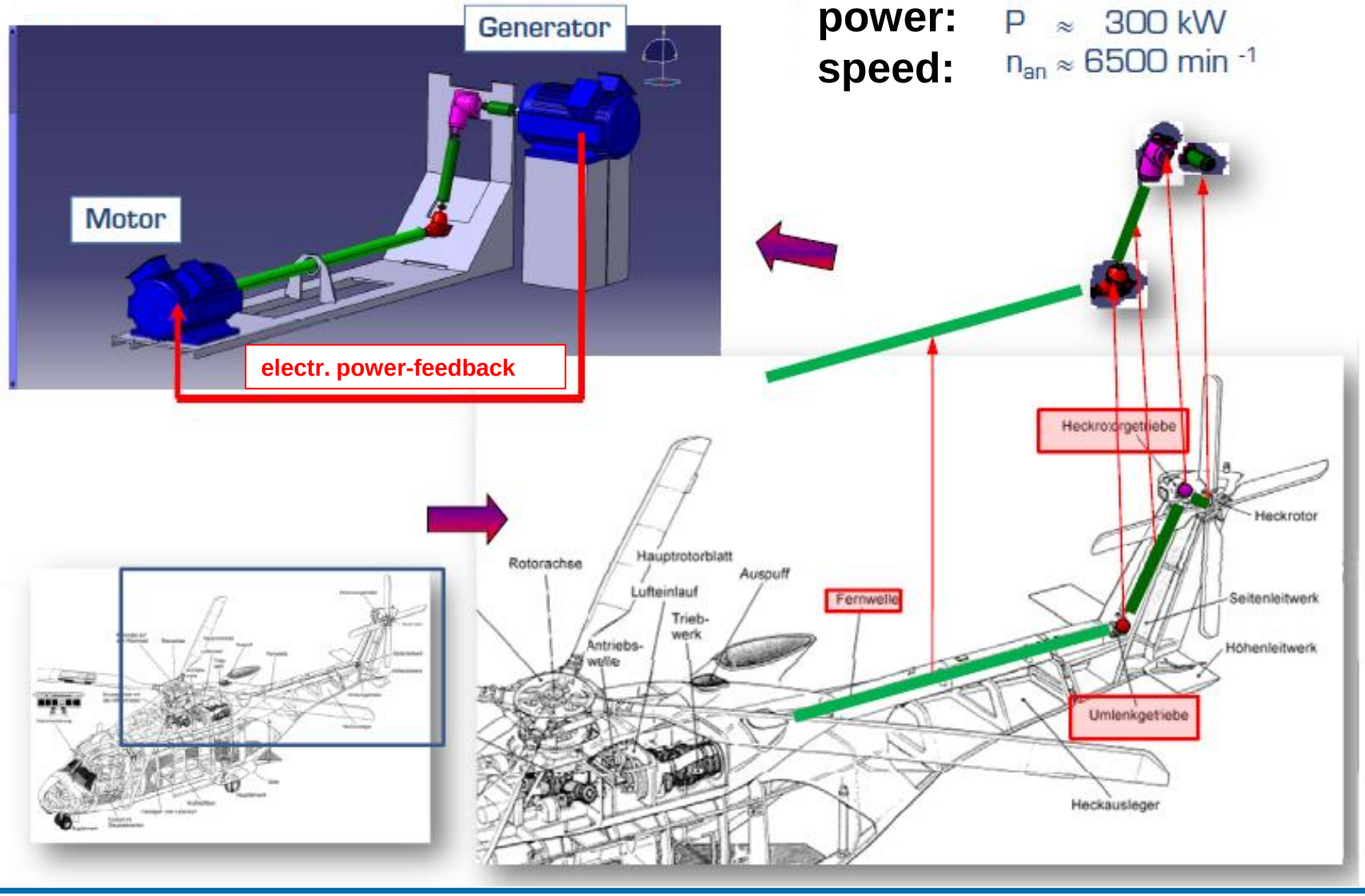


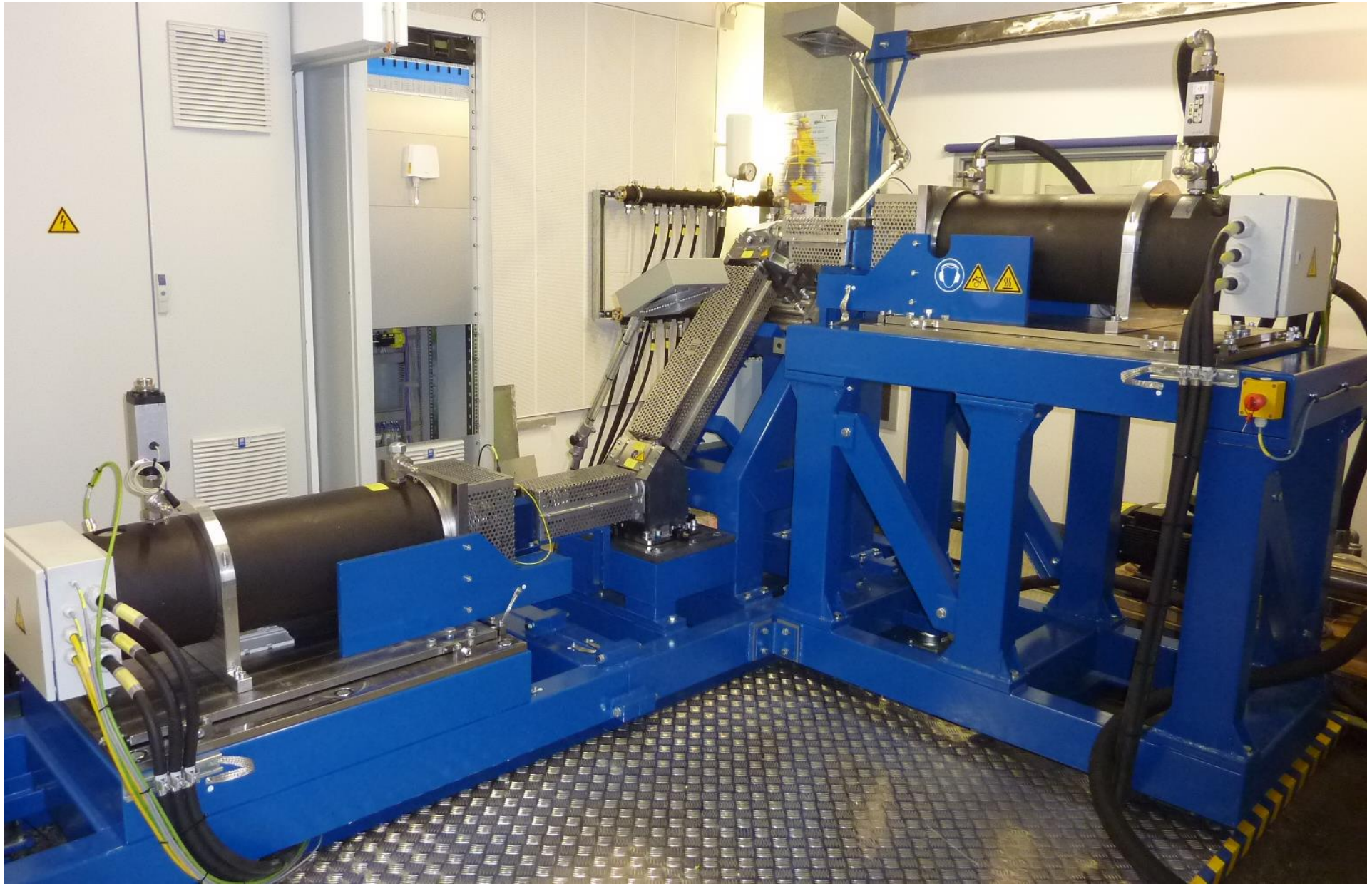
SCHENCK
Balancing Machine




TU
WIEN
TECHNISCHE
UNIVERSITÄT
WIEN
Vienna University of Technology
Microsoft

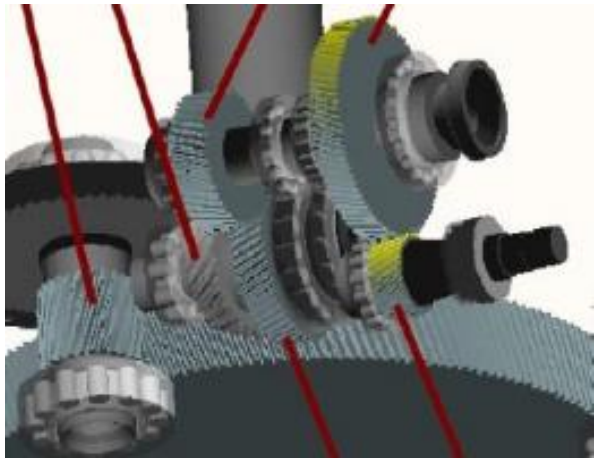
Universal Test Stand





ZOERKLER
the spirit of precision

TECHNISCHE
UNIVERSITÄT
WIEN
Vienna University of Technology



ZOERKLER
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TECHNISCHE UNIVERSITÄT WIEN
Vienna University of Technology

Zoerkler Gears in Jois / Austria

ZOERKLER
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TECHNISCHE
UNIVERSITÄT
WIEN
Vienna University of Technology

FFG

bmvit
Bundesministerium für Verkehr, Innovation und Technologie

Luftfahrtforschungs-programm (LuFo V)

Bundesministerium für Wirtschaft und Energie

TECHNISCHE UNIVERSITÄT MÜNCHEN

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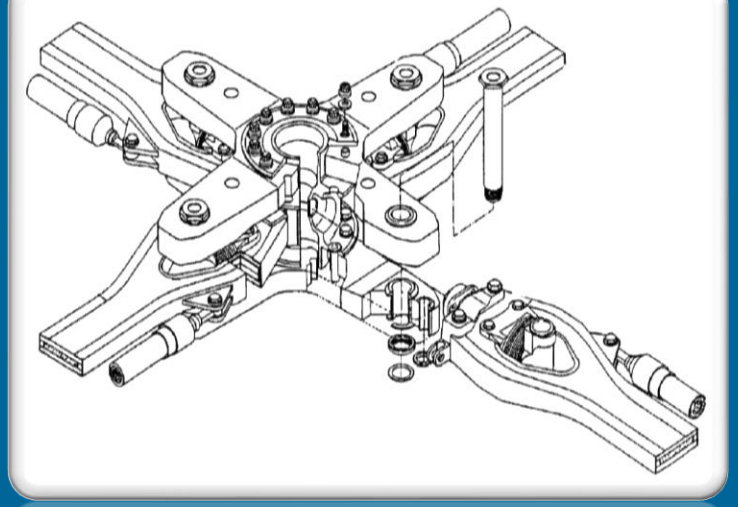
TU WIEN TECHNISCHE UNIVERSITÄT WIEN

VARI-SPEED

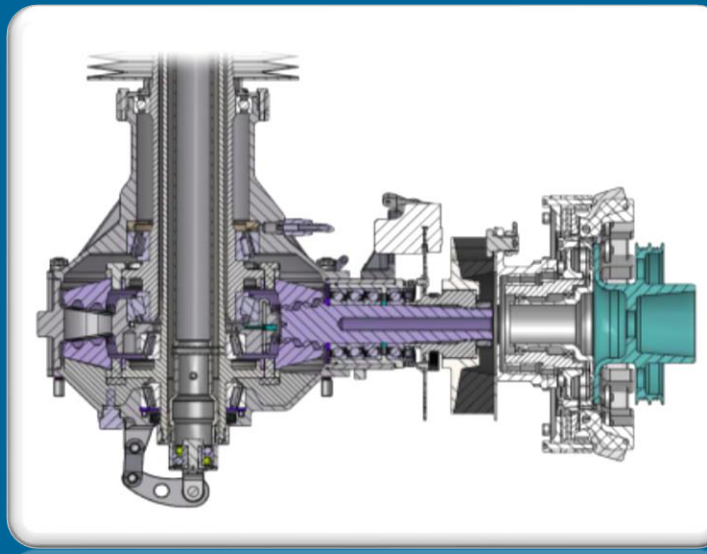
Variable Speed Rotorcraft Drive System

LEHRSTUHL FÜR HUBSCHRAUBERTECHNOLOGIE

Forschungsbereich Maschinenelemente und Rehabilitationstechnik



Rotor for variable Rotor Speed



Transmissions for variable Rotor Speed with constant Turbine Speed

TECHNISCHE UNIVERSITÄT MÜNCHEN

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TU WIEN TECHNISCHE UNIVERSITÄT WIEN

IFAR Initiative „Vertical Lift“

International Level

Continental Level

National Level

Harmonized Activities

Unbiased expertise

TU Wien – as University – has a unique view on rotorcraft transmissions and rotorcraft safety, different from the view of OEM´s, operators and authorities.

Being familiar with the regulatory framework, especially Certification Specifications CS-VLR, CS-27 and CS-29 and all related Guidance Material, all activites in research and teaching are done place against this background take this regulations into account in each activity from the very beginning.

TU Wien is willing to bring in this expertise into EASA´s activities and rotorcraft safety activities.

We are interested to discuss and share our activities and views here during European Rotors 2021 – **visit us at D – 123!**

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Integrity improvement of MGB

The research unit has developed a dedicated, systematic research approach to improve the integrity of rotorcraft main gearboxes (MGB).

This concept echoed the corresponding EASA call (Publication Reference: EASA.2019.HVP.17).

TU Wien and its partners proposed alternative approaches for detection of the degradation of critical parts. This approach is suitable for all transmissions for aviation.

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Safety assessment & FMECA

EASA started the Notice of Proposed Amendment 2021 – 11 in October 2021 (NPA 2021-11) ‘Enhancement of the safety assessment processes for rotorcraft designs´

TU Wien is willing to contribute actively to the objectives of the proposed amendment.

Based on an accident report which was made public, TU Wien defined and tested a concept for a modular and software-based Failure Mode Effects and Criticality Analysis (FMECA). It could be shown that the FMECA can be integrated fully into the design process, especially for continuing airworthiness.

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Detection of abrasion & status monitoring

The rulemaking task RMT.0725 was initiated by the EASA to improve chip detection in rotorcraft gearboxes. TU Wien offers its scientific findings and independent expertise to these working groups and to NPA 2021 - 01.

INMOX, a startup company based in Vienna, has developed a new concept for the smart (**“hard chip ?”**) detection of dangerous metal chips and particles, including the proof of concept. This innovation is closely linked to the RMT.0725 and to the research unit Transmissions for Aviation at TU Wien.
TU Wien is testing these new chip detectors on its transmission test stands.

Detection of abrasion & status monitoring (cont.)

A fatal incident occurred in 2016 that was not indicated by abraded chips or particles. This provided evidence that critical parts like gears and bearings can also degrade to a catastrophic degree without being detected early enough by chip detection, which must be further investigated.

TU Wien and partners have elaborated a concept for this investigation in the frame of MGB integrity improvement.

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Freewheel operation

Freewheel clutches have proven to be very sensitive transmission components. TU Wien has compiled and analysed the information available on details of mechanical components, operational experience and reported incidents involving freewheel clutches.

Freewheel operation

TU Wien elaborated a **concept for theoretical and experimental investigations including a dedicated test rig to analyse the engagement and disengagement of freewheel clutches** and the effect of longer overrunning phases e.g. in intended single engine operation (ISEO).

Freewheel clutches in drivetrains powered by piston engines and their specific demands are also investigated.

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The lubrication of the helicopter MGB poses several conflicting requirements.

- Lubrication of output stages highly loaded and at low speed would require thick, EP additivated gear oils
- Lubrication of input stages lightly loaded and at very high speeds, including freewheeling clutch assemblies would require thin, non EP, oils
- Operating ranges from typically –40°C to +50°C possibly with a single oil
- Commonality of MGB oils with the turbine engine synthetic oils
- Largest range of oil brands to satisfy Customer economic and availability requirements

Source: G. Gasparini, N. Motta, G. Straulino: The „035“ MainGearBox: Strong, Light, Reliable and Silent Heart of the AW139 Helicopter AHS 2007

All the above lead to a compromise choice: i.e. adopting for the entire MGB a thin synthetic turbine engine oil liked by the engine manufacturers and generally compliant and qualified against MIL-PRF-23699 (NATO O-156 in Europe).

Therefore, the MGB has been designed and qualified in order to operate with the most common type of turbine engine oils (e.g. according to the US specification MIL-PRF-23699) avoiding the recourse to more specific or sophisticated oils which could have imposed the need of dealing with different oil for the engine and for the transmission.

Source: G. Gasparini, N. Motta, G. Straulino: The „035“ MainGearBox: Strong, Light, Reliable and Silent Heart of the AW139 Helicopter AHS 2007

This is an advantage which is appreciated by both the civil and military operators. The former because they have the economic advantage of a broader range and of buying larger quantities, the latter because they simplify the huge inventories by reducing the different type of oils stocked.

However it represents a compromise for the MGB and poses several challenges and eventually limitations to the gearbox specialist.

It is therefore hoped that, in the future, the Customers will recognize this fact and will be more open to support the additional logistic burden of dealing with 2 oil families: one for the turbine engines and another one for the gearboxes, in order to achieve the full reliability potential for both.

Source: G. Gasparini, N. Motta, G. Straulino: The „035“ MainGearBox: Strong, Light, Reliable and Silent Heart of the AW139 Helicopter AHS 2007

Gearbox oils will be in the range of 5 to 9 Centi-Stokes with specific additives for improving their load carrying capacity for gears contact (scuffing and micro-pitting primarily) and for bearings contact (micro-pitting and pitting) and their corrosion preventive capabilities.

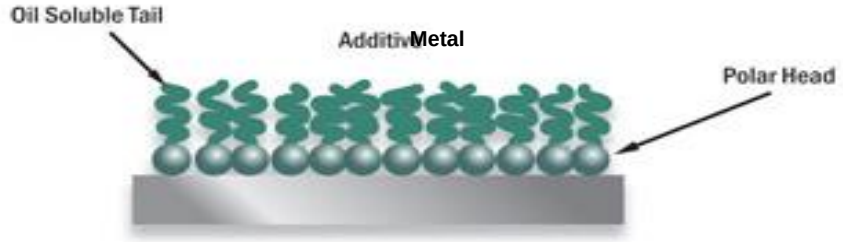
Source: G. Gasparini, N. Motta, G. Straulino: The „035“ MainGearBox: Strong, Light, Reliable and Silent Heart of the AW139 Helicopter AHS 2007

Base Oil

- Prevent metal-metal contact
- Cleaning and suspending
- Transfer heat from metal surfaces

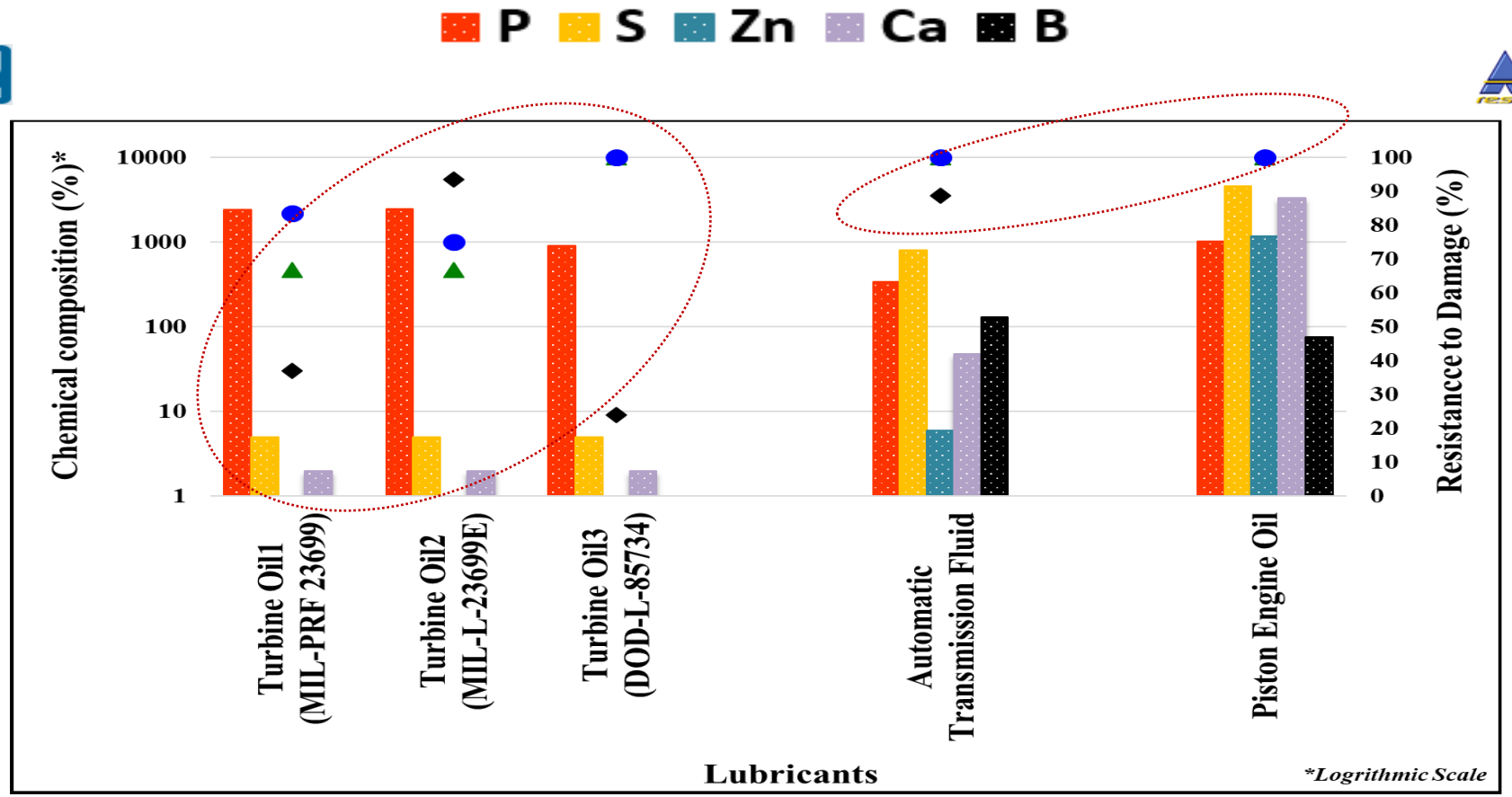
Additives

- Enhance an existing property
- Add a new property
- Suppress undesirable property



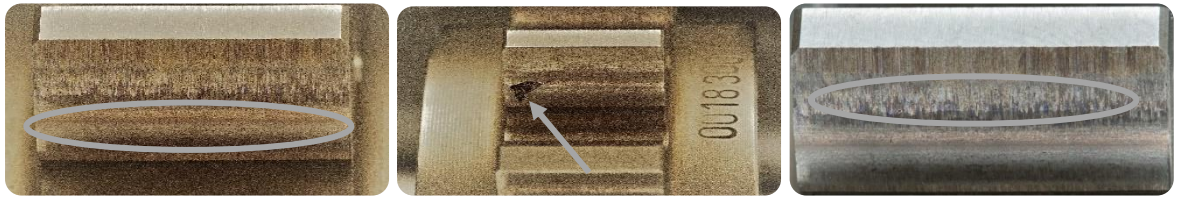
Additives	Engine Oils	ATF	General R&O Oil	AW Hydraulic	Industrial Gear Oil	Automotive Gear Oil	Grease
Detergents	✔	✔					
Dispersants	✔	✔					
Anti-Oxidants	✔	✔	✔	✔	✔	✔	✔
Rust Inhibitors	✔	✔	✔	✔	✔	✔	✔
Anti-Wear	✔	✔		✔	✔	✔	✔
Extreme Pressure Agents					✔	✔	✔
VI Improvers	✔	✔		**High VI**	**Some**	**Some**	
Pour Point Depressants	✔	✔	✔	✔	✔	✔	
Anti-Foam	✔	✔	✔	✔	✔	✔	
Friction Modifiers	✔	✔					

Source: Petro Canada



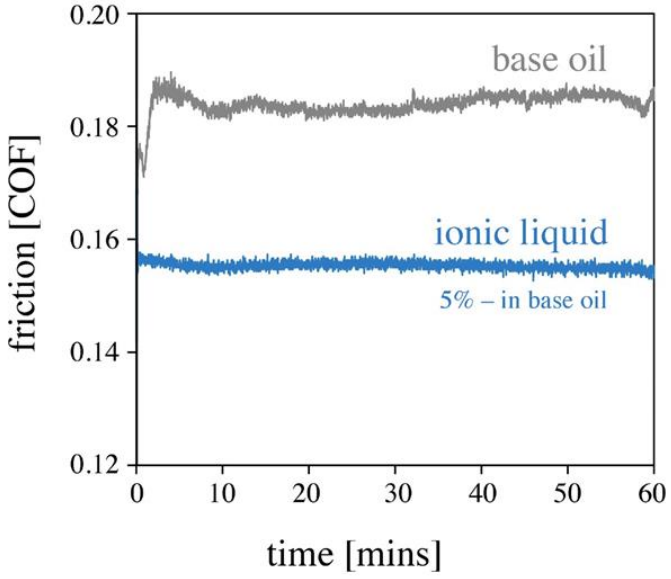
FZG - back-to-back
IAE - gear
Ryder - test rig

▲ Micropitting ◆ Pitting ● Fretting

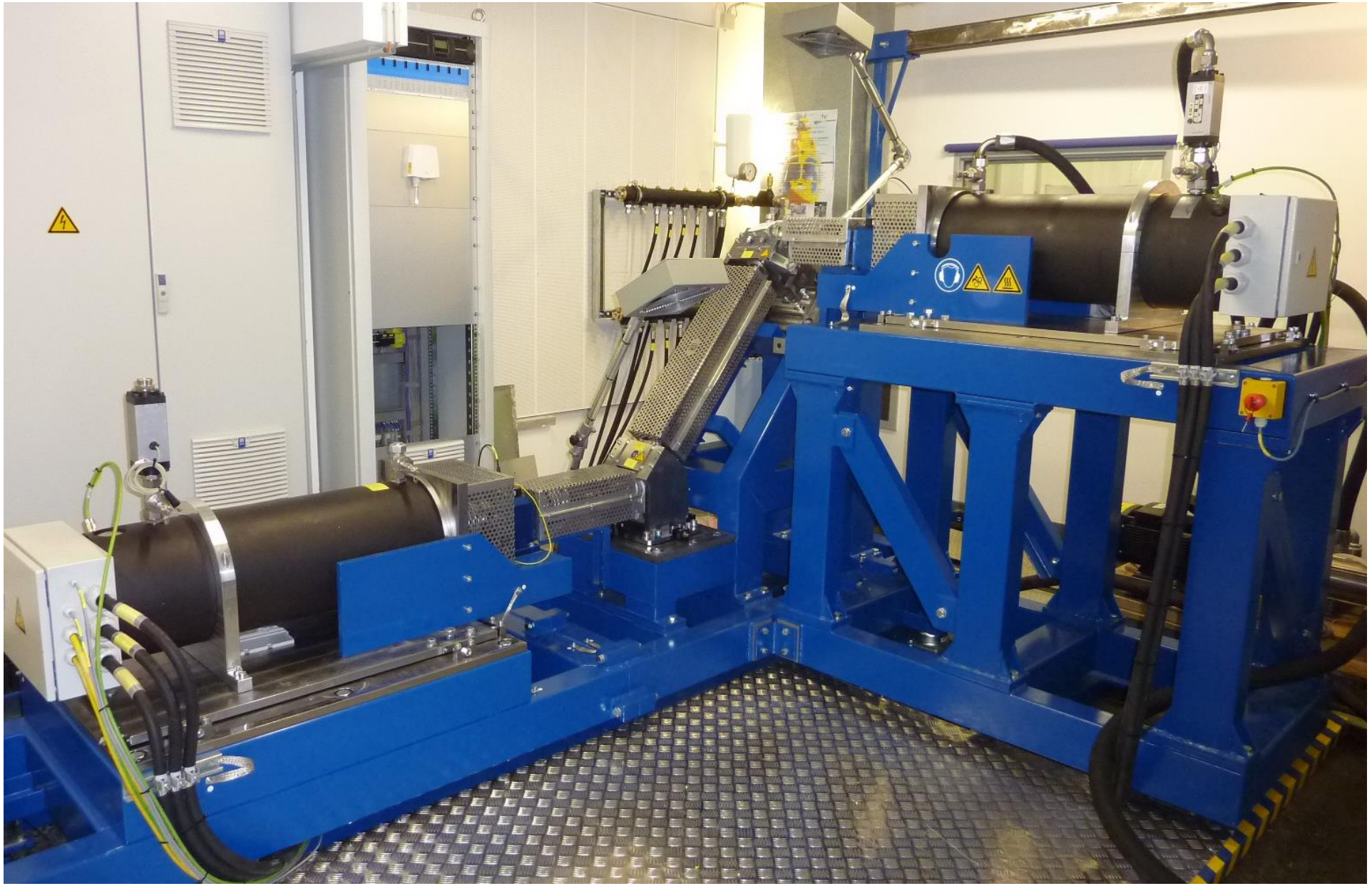


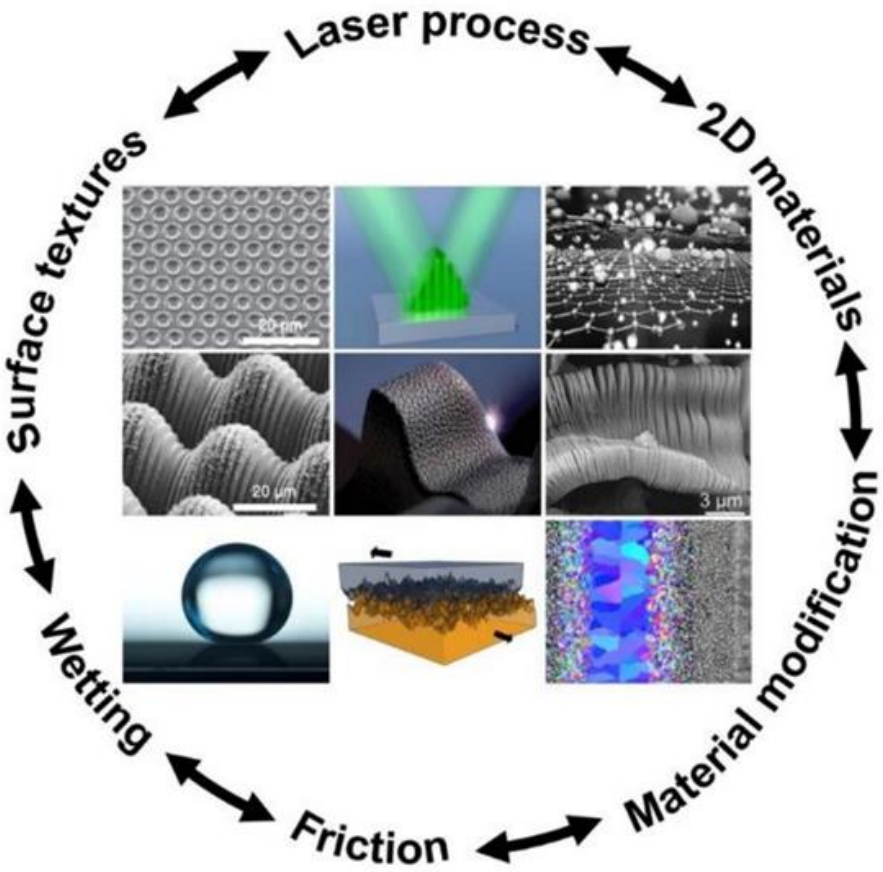
Existing lubricants were characterized and **new additives (ionic liquids)** were developed and tested successfully on FZG – and tribological test benches in combination with FVA - reference oils.

The figure clearly illustrates that the friction measured for the ionic liquid blend with base oil is much lower compared to common oils.



Now these additives are about to be tested and tried in combination with certified oils (like oils acc. to MIL-PRF 23699) using original rotorcraft gearboxes.





New lubrication concepts and tailored surfaces
spawned by interdisciplinary co-operation at TU Wien

Also new 2D and 3D materials as well as advanced surface structures for improved lubrication are being developed.

Lubricants & loss of lubrication (cont.)

Rule making task RMT.0608 regarding loss of lubrication was initiated by EASA following misinterpretations of Certification Specifications CS-29 for Large Rotorcraft, especially § 29.927(c).

TU Wien is willing to supply independent scientific expertise to these discussions and working groups.

TU Wien is working on concepts to enable the **evaluation of the loss-of-lubrication performance in early design stages**.

Unbiased expertise

TU Wien – as University – has a unique view on rotorcraft transmissions and rotorcraft safety, different from the view of OEM´s, operators and authorities.

Being familiar with the regulatory framework, especially Certification Specifications CS-VLR, CS-27 and CS-29 and all related Guidance Material, all activites in research and teaching are done place against this background take this regulations into account in each activity from the very beginning.

TU Wien is willing to bring in this expertise into EASA´s activities and rotorcraft safety activities.

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Visit us at D-123

to share views and discuss

rotorcraft safety!

Thanks for Your Attention !