10TH EASA Rotorcraft Symposium

Cologne, 6-7 December 2016

HOW CAN WE FURTHER IMPROVE ROTORCRAFT TRANSMISSIONS ?

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Institut für Konstruktionswissenschaften und Technische Logistik

TU WIEN

Forschungsbereich Maschinenelemente und Rehabilitationstechnik

How can we further improve rotorcraft Transmissions?

Overview

1. Transmissions for aviation at TU Wien
2. Improvement: Technology
3. Improvement: Lubrication and Loss of Lubrication
4. Improvement: Simulation and Calculation
5. Improvement: Design Assessment (FMECA)
6. Future trends, requirements and activities

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Classes / Courses 307 - 3 for Bachelor (E033 245) und Special Focus Design for Master (E066 445)										
according to official Course Tables Mechanical Engineering, dated 01.10.2006, Version 2 valid since 01.10.2008										
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*	Basics of Machine Elements	Basics of Machine Elements		Bachelor Thesis	Machine Design	Machine Design		Master Thesis
	VU 2/307-1	*VO 2/307-1*	VO 3	KU 3		PA 6	VO 2	KU 5		
	307.052	*307.016*	307.061	307.062		307.058	307.066	307.070		
		Techn. Drawings CAD					Machine Design			
		KU 3/307-1					RU 1			
		307.017					307.067			
							Machine Design	Trans-missions (for Aviation)	Trans-missions (for Aviation)	
VO – Lectures / KU/RU – Exercises / LU – Laboratory Courses							LU 2	VO 2	SE 2	
SE – Seminar / PA – Project work							307.068	307.082	307.083	
							Machine Design	Trans-missions (for Aviation)	Trans-missions (for Aviation)	
							SE 2	LU 2	PA 5	
							307.069	307.084	307.085	
								Special Machine Elements		
								VO 2		
								307.063		
SWS total:			3	3		6	6	11	7	

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Special Courses about Transmissions for Aviation

FVA
Forschungsvereinigung Antriebstechnik e.V.

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

AGMA
American Gear Manufacturers Association

AHS INTERNATIONAL
THE VERTICAL FLIGHT SOCIETY

TU WIEN
VGR
Vienna Gear²ing

IFAR | INTERNATIONAL FORUM FOR AVIATION RESEARCH

AAI - Austrian Aeronautics Industries Group
Interessensgemeinschaft der Österreichischen Luftfahrtzulieferindustrie

AIRMED
PRAHA 2008

AIR MED
24-27 MAY
WORLD CONGRESS BRIGHTON 2011

WiGeP

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Mechanical Engineering - Laboratory:
General View after Re-Opening in July 2009

Mechanical Engineering – Laboratory: Tail drive shaft testing

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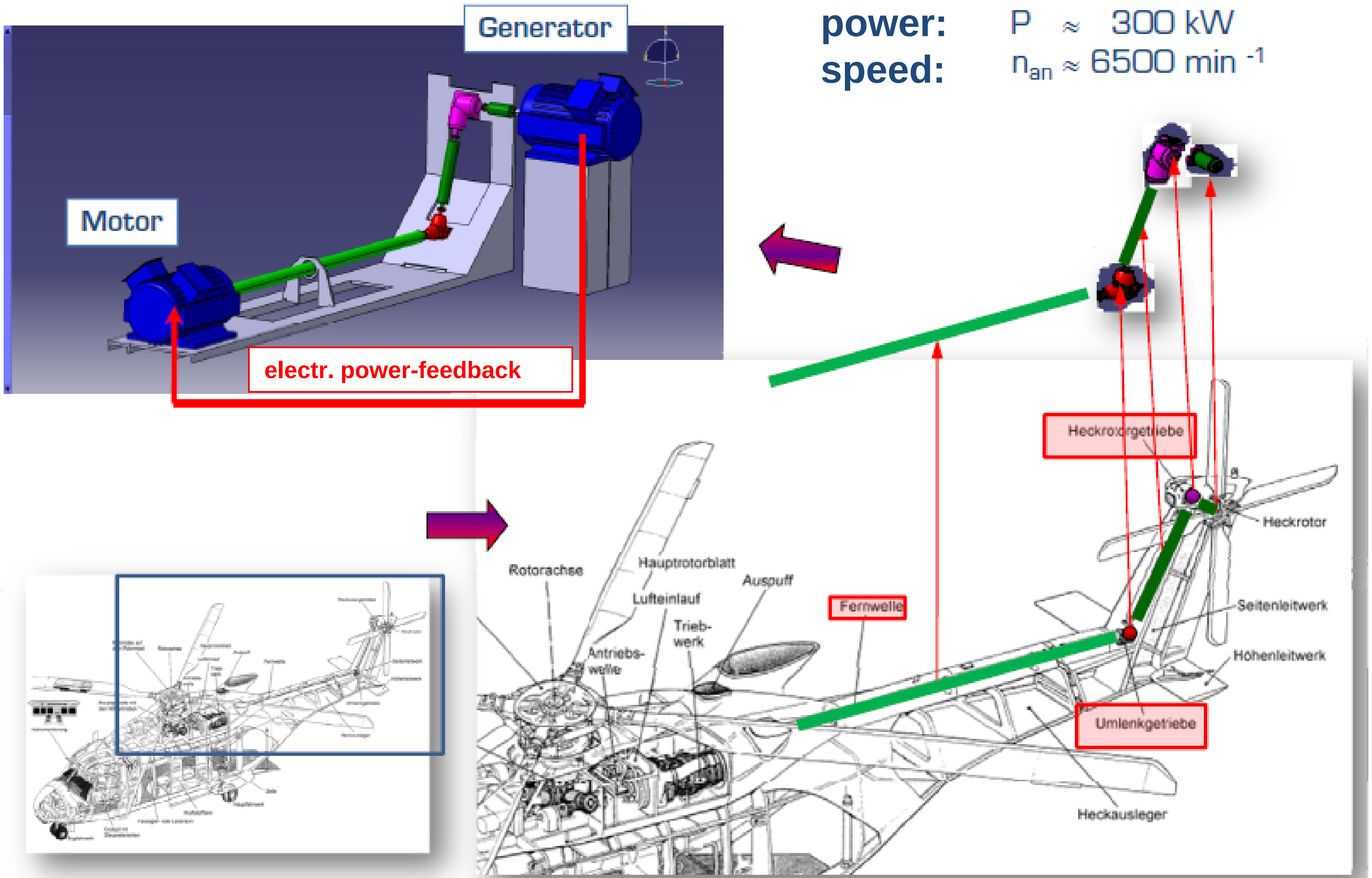
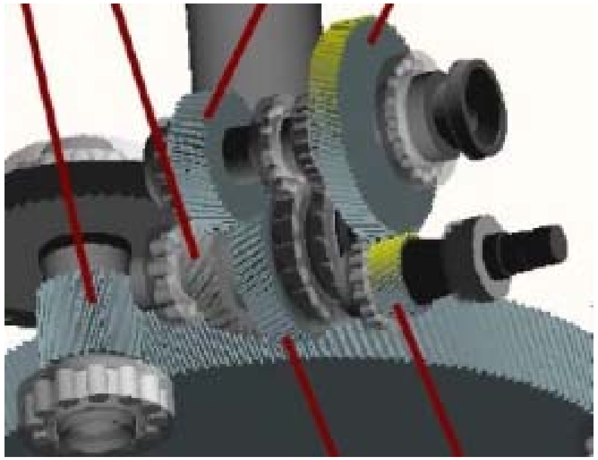
Universal Test Stand
- in realisation -

power: $P \approx 300$ kW
speed: $n_{an} \approx 6500\ \text{min}^{-1}$



Maschinenelemente-Labor: Universal - Prüfstand 300kW



ZOERKLER
the spirit of precision

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Drivetrain Development

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Continuous Improvement of Transmissions

- Materials
- Calculation
- Lubricants
- Sealings
- HUMS

Optimiertes Getriebegehäuse

ILA Berlin Air Show 2010

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

LUBRICATION

(Gasparini, G.; Motta,N.; Straulino, G.:
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.

LUBRICATION

(Gasparini, G.; Motta,N.; Straulino, G.:
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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.

LUBRICATION

(Gasparini, G.; Motta,N.; Straulino, G.:
The „035“ MainGearBox: Strong, Light, Reliable and Silent Heart of the AW139 Helicopter.
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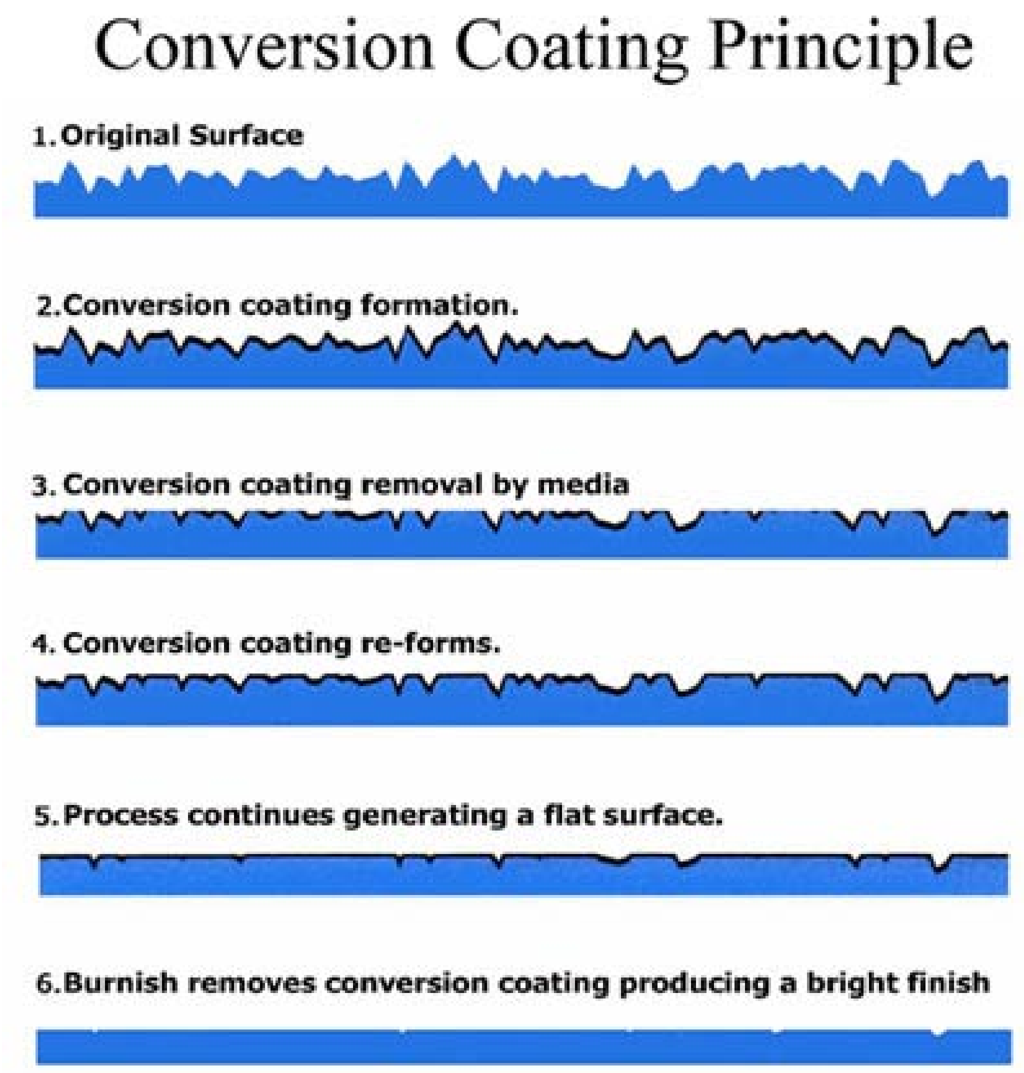
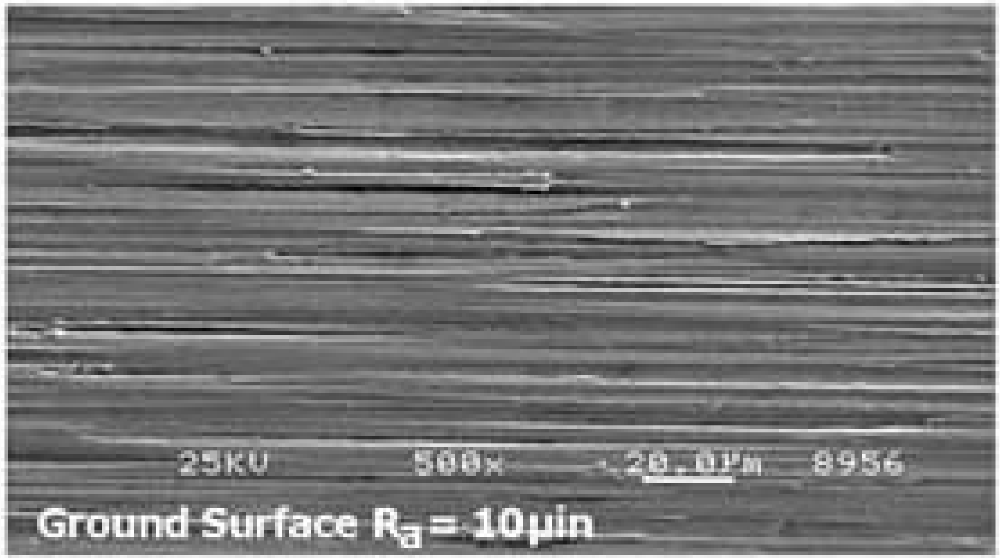
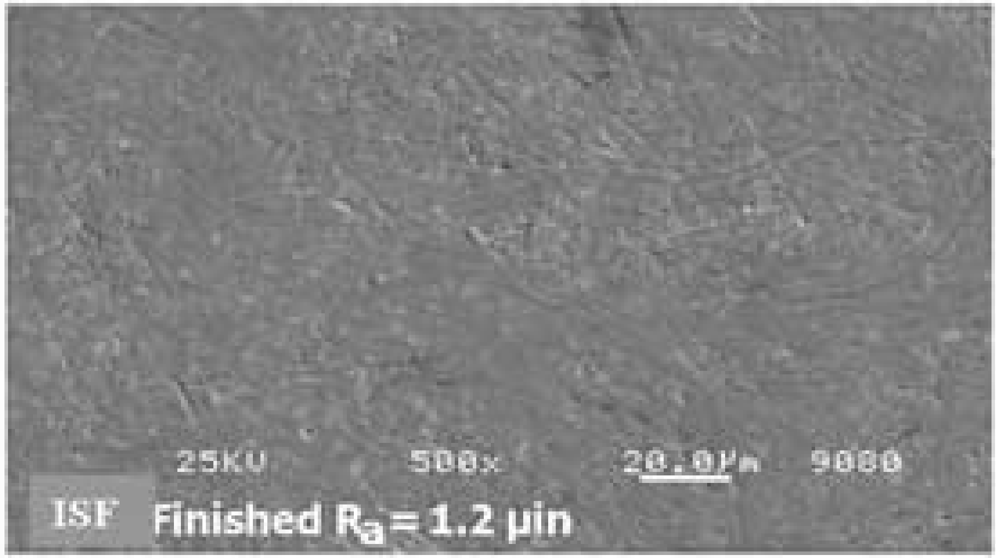
PROPERTIES		MIL-PRF-23699F Grade STD	TYPICAL
Oil Type		Synthetic ester	Synthetic ester
Kinematic Viscosity	mm²/s		
@ 100°C		4.90 to 5.40	5.17
@ 40°C		23.0 min	25.26
@ –40°C		13000 max	8996
Flashpoint, Cleveland Open Cup	°C	246 min	256
Pourpoint	°C	–54 max	<–54
Total Acidity	mgKOH/g	1 max	0.01
Evaporation Loss 6.5 hrs @ 204°C	% m	10.0 max	2.52
Foaming		Must pass	Passes
Swelling of Standard Synthetic Rubber			
SAE-AMS 3217/1, 72 hrs @ 70°C	swell %	5 to 25	Within Limits
SAE-AMS 3217/4, 72 hrs @ 204°C	swell %	5 to 25	Within Limits
standard silicone rubber 96 hrs @ 121°C		5 to 25	Within Limits
Thermal Stability/Corrosivity 96 hrs @ 274°C			
– metal weight change	mg/cm²	4 max	0.5
– viscosity change	%	5 max	2.69
– Total Acid Number Change	mgKOH/g	6 max	2.03

OIL ACCORDING TO MIL-PRF 23699



CHEMICALLY ACTIVATED SUPERFINISHING





CHEMICALLY ACTIVATED SUPERFINISHING

Helicopter Tail Rotor Drive

Bevel gears after chemically activated superfinishing

FFG

bmvit

Austrian Ministry
for Transport,
Innovation and Technology

2011 - 2014: Nationally funded research project:

Optimised

Helicopter Transmissions

OHA!

Made in Austria

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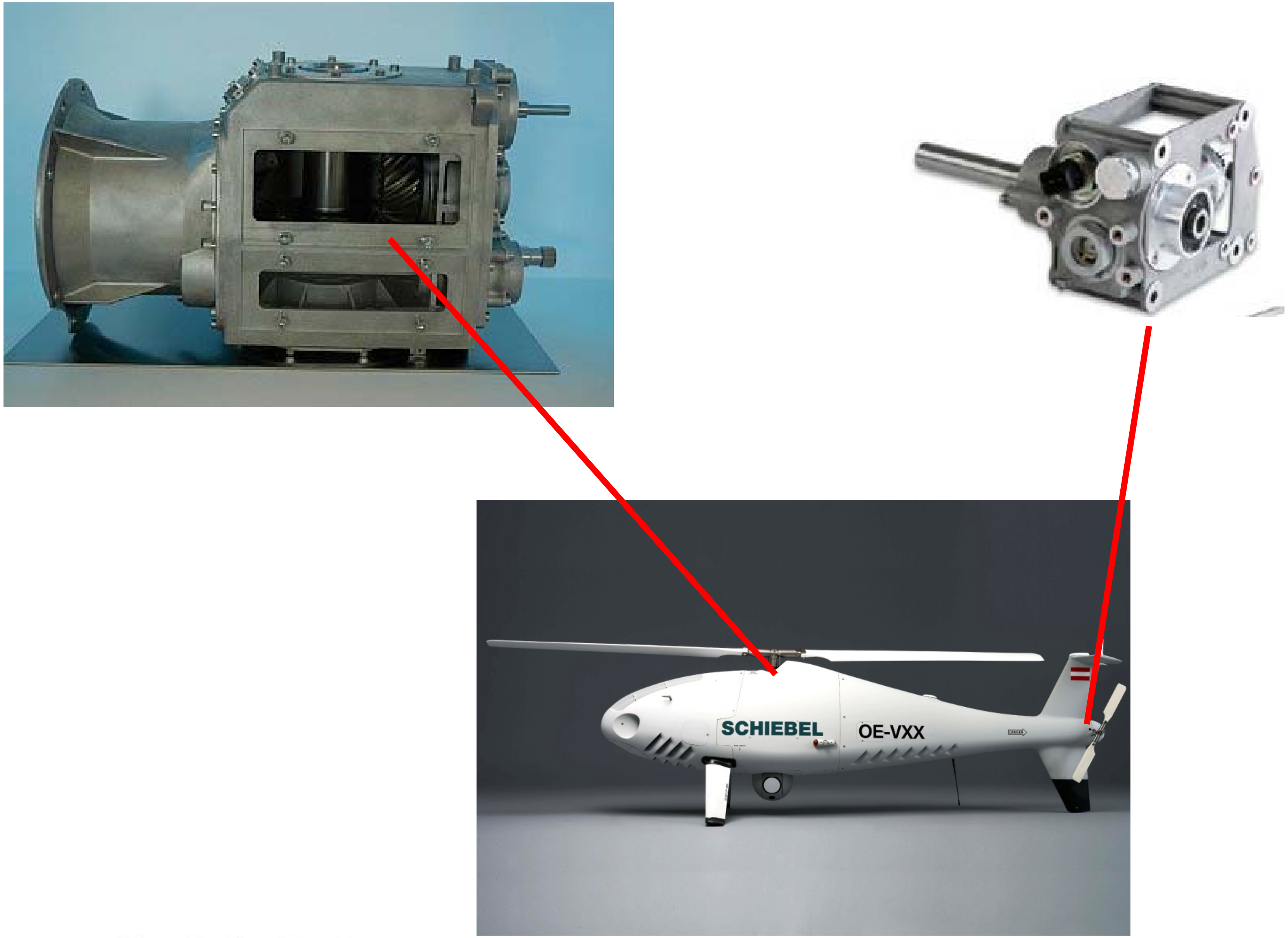
SCHIEBEL

pankl AEROSPACE

OHA!: Nationally funded research project



OHA!

Schiebel camcopter S-100

OHA!

Tail Drive of CS-27 Helicopter

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Loss of Lubrication

- **Technical Improvements:**

  Lubricants, Emergency Lubrication, Coatings, Surface Treatment etc.

- **Simulation and Calculation:**

  Realisation of a calculation method that enables to evaluate the loss-of-lubrication behaviour in early design stages

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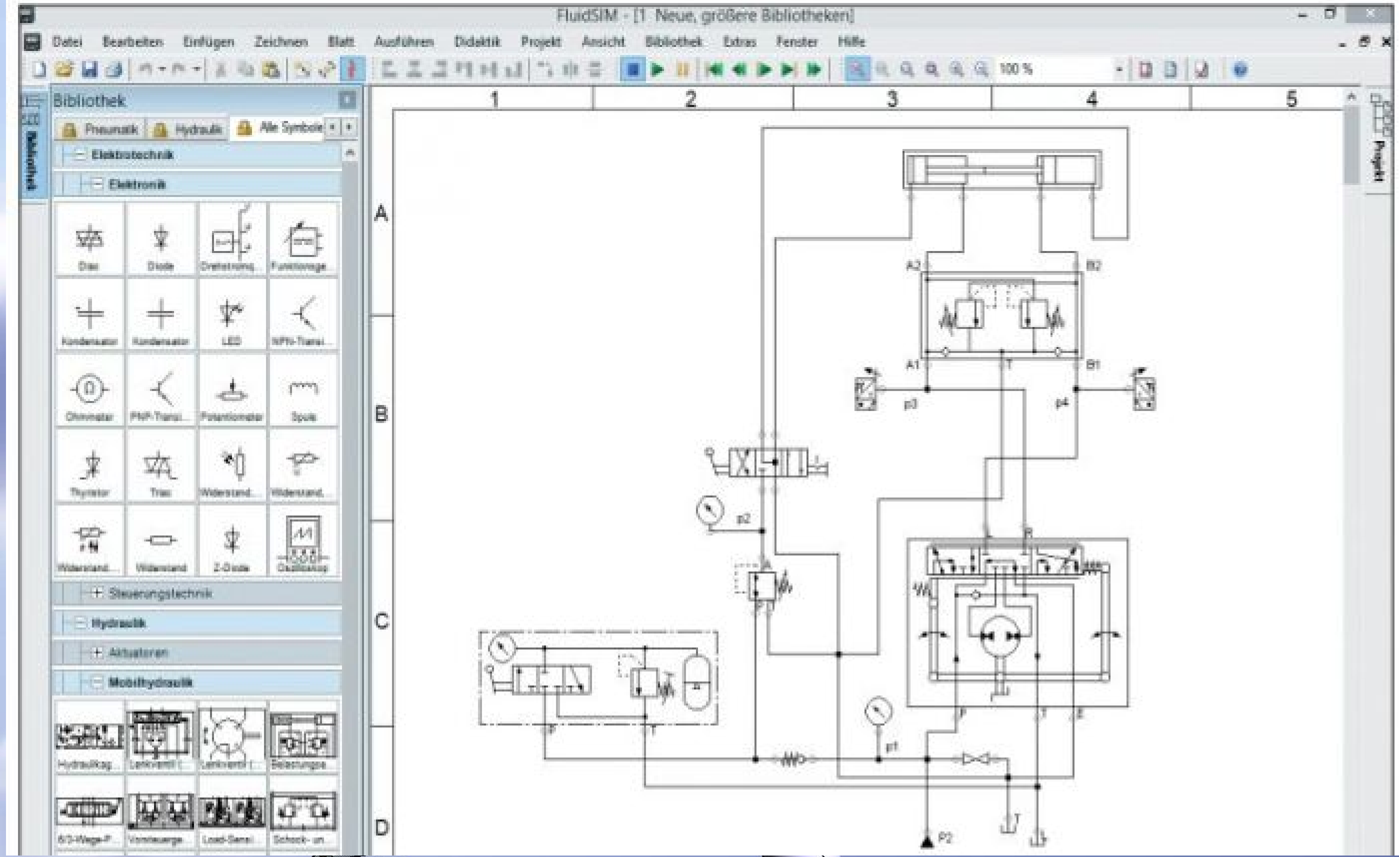
Simulation and Calculation

- Calculation of Gears, Bearings and Shafts
- Calculation of Heat Transfer
- Simulation of Loss of Lubrication
- Simulation of Chip Detection



Source: FluidSIM

HYDRAULIC SIMULATION

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FMECA

Lessons to be Learned from Helicopter Accidents involving Transmissions

- **Continuous follow-up after incidents**

- **FMECA as continuous procedure fully integrated in design process**

- **Software support**

- **Modular FMECA**

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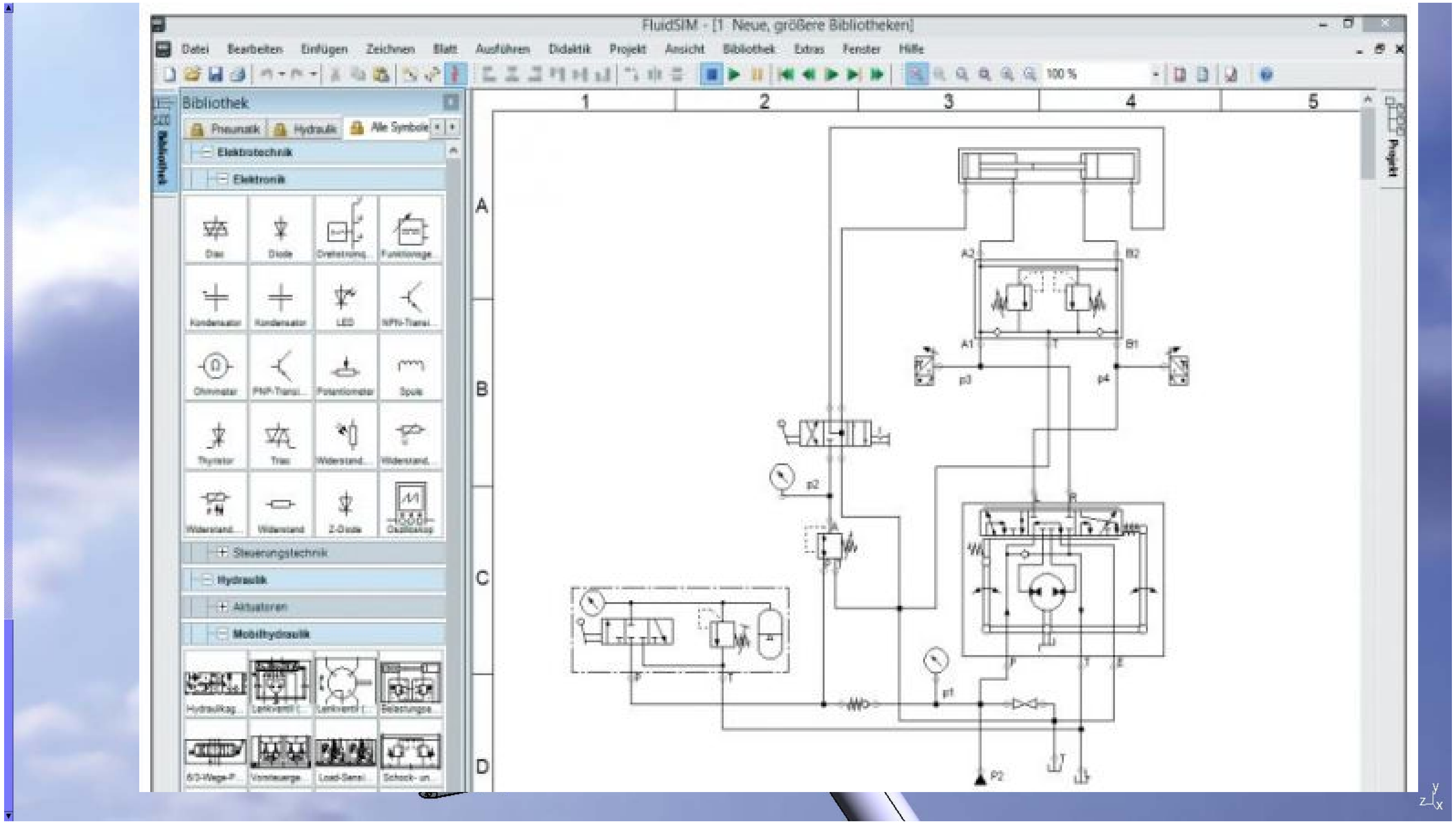

Source: itemsoft

FMECA SOFTWARE TOOL

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Future trends, requirements and activities

- Continuous Technical Improvements
- Continuous Basic Research
- Validated and universal design tools
- Enlarged operation time under loss-of-lubrication conditions
- Improved, robust and standardized HUMS systems
- Close cooperation between OEM´s, operators, EASA, designers, universities and research facilities

EASA
European Aviation Safety Agency

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Thanks for Your Attention !