



Dynamic Simulation of a Rotorcraft Main Transmission with Continuous Variable Ratio

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<u>Agenda</u>

- 1. Transmissions for aviation at TU Wien
- 2. Introduction: Variable Speed
- 3. Modeling and Simulation of the Transmission with variable speed including Compound Split
- 4. Conclusions, Next Steps



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Classes / Courses 307 - 3 for Bachelor and Special Focus Design for Master										
Date: 27.11.2017										
	BAGUELOB	DAGUELOD	DAGUEL OD		DAGUELOD		MAGTER	MAGTER	MAGTER	MAGTER
Comostor	BACHELOR	BACHELOR	BACHELOR	BACHELOR	BACHELOR	BACHELOR	MASTER	MASTER	MASTER	MASTER
Semester		2	5	4	5	0	1	2	<u> </u>	4
	Techn. Drawings CAD	Basics of Design	Machine Elements	Machine KU in 4. d	Elements 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 / 3	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
				307.4	49 (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)
	ECTS credits a	re shown in bra	rkets					Special Maschine Elements	Special Maschine Elements	
			ionoto					307.456 (3)	307.457 (4)	
	BACHELOR	BACHELOR	BACHELOR	BACHELOR	BACHELOR	BACHELOR	MASTER	MASTER	MASTER	MASTER
Semester	1	2	3	4	5	6	1	2	3	4

- Special Courses about Transmissions for Aviation
- Professorship for Tribology (Prof. Gachot) since 2016
- Professorship for Aircraft Systems (Prof. Berens) since 2021
- Master course "Aeronautical Engineering"





Forschungsvereinigung Antriebstechnik e.V.





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













June 28 – 30



Memberships and representations





Laboratory Transmissions for Aviation: General View

Universal Test Stand







Laboratory Transmissions for Aviation: Universal test stand 300kW





Laboratory Transmissions for Aviation: Universal test stand 300kW









Ka-62 Type Certification 1st December 2021





Drivetrain Development











Zoerkler Gears in Jois / Austria









Zoerkler Gears: Main Gear Gearbox Teststand (2 x 2600kW)











"KOKON" - New Interior Concept for EMS helicopters

IFAR Initiative "Vertical Lift"



FFG

Republic of Austria Climate Action, Environment, Energy, Mobility, Innovation and Technology

National Level

Harmonized **Activities**









IFAR – International Forum for Aviation Research

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 with this background and take these

regulations into account in each activity from the very beginning.



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Federal Ministry Republic of Austria Climate Action, Environment, Energy, Mobility, Innovation and Technology



Variable Speed Rotorcraft Drive System

Luftfahrtforschungsprogramm (LuFo V)



Bundesministerium für Wirtschaft und Energie













Transmissions for variable Rotor Speed with constant Turbine Speed











VARI-SPEED



Reference: Sikorsky UH-60 Blackhawk



Racer readied to reach first flight milestone



By Dominic Perry, Marseille | 14 February 2024

Airbus Helicopters is increasingly confident that its Racer technology demonstrator will be airborne in the coming weeks, with assembly of the high-speed rotorcraft now largely complete.



FlightGlobal

Final quality inspections on the completed aircraft and its subsystems are currently taking place at the manufacturer's facility in Marignane in southern France as it targets a first flight "in the coming weeks", says Racer programme manager Julien Guitton, briefing journalists on 13 February.

Once those checks are completed, the Racer will be moved to the flight line for the ground runs and pre-flight calibration essential to obtaining a permit to fly; that activity is expected to last for around two weeks.

"Then it will be the first flight," says Guitton. "Our target is the end of March."

When airborne, Airbus Helicopters will progressively open the Racer's envelope, targeting to reach its maximum cruise speed of 220kt (407km/h) within around six months.

Vollständiger Artikel auf LRZ-Server verfügbar









Next Generation Civil Tiltrotor takes shape as Leonardo eyes first flight milestone



By Dominic Perry | 13 February 2024

Leonardo Helicopters is close to completing the final assembly of its Next Generation Civil Tiltrotor (NGCTR), as it prepares the demonstrator for a maiden sortie before the summer.







FlightGlobal

Harder to predict though is when that flight will happen. Besides expressing confidence that it will take place this year, Biggi is reluctant to offer a firm forecast. However, he adds: "If we are lucky and everything is going well, in some months we could manage to have the first flight, maybe with some limitations.

"I think in a few months we should be able to fly." Does that mean by the summer? "Maybe before," 3.

Vollständiger Artikel auf LRZ-Server verfügbar





Next Gen CTR: Actual pictures vs. earlier impressions – reduced size / pax / MTOW?



Vari-Speed III: Possible Approaches



Next Gen CTR vs. AW 609



Vari-Speed III: Possible Approaches



VARI-SPEED phases

- VARI-SPEED I showed the feasibility of a rotor system with variable speed
- VARI-SPEED II focuses on dynamic simulations of the whole drivetrain

and evaluation in a simulator environment

VARI-SPEED III is intended to aim at (scaled) prototypes



VARI-SPEED II



- Dynamic model of the turbine
- Layout of the "compound split" transmission system

including variator for speed variation and dynamic model

- Dynamic model of the rotor
- Design of different controllers for simulation of the whole drive system
- Flight Simulator Evaluation



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Arrangement of original drive train UH 60-A





Layout of UH-60 transmission system

© IKP TU Wien









Architecture 1 with one compound split and one variator after the bevel gear ⁴⁰

ataga





Architecture 2 with two compound splits and two variators before bevel gear stage 41





Power flow for architecture 1 (left) and architecture 2 (right)

44









Principal depiction of the transmission drivetrain, extended by the compound split ⁴⁶





: UH-60 transmission system as model in FVA-Workbench ®



compound split (framed in red), consisting of the left planetary stage (framed in blue) and the right planetary stage (framed in green)



48



connecting shaft between carrier of left planetary stage and the ring gear of right planetary stage is shown transparent







: UH-60 transmission system as model in FVA-Workbench®





60





Structure of the dynamic model created with Simulink Simscape Multibody[®] ⁶¹





Simulation model of the compound split, modelled with Simscape Multibody[®] ⁶²





Power flow in mechanical point 1 - lowest main rotor speed





Power flow in mechanical point 2 - highest main rotor speed



	Input speed	Main rotor speed	Variator output	Variator input
	n _a	n _{MR}	n _c	n _d
	[rmp]	[rmp]	[rmp]	[rmp]
Original UH60-A	5750	258	-	-
MP 1	5750	189	1509	0
MP 2	5750	284	0	1195



Overview of the speeds of the most important operating points



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VARI-SPEED II (2021 - 2024)

- Dynamic model of the turbine near completion completed, under validation
- "compound split" transmission system including variator for speed variation defined
 - Dynamic model and initial design phase, under validation
- Dynamic model of the rotor under way completed, under validation
- Development of different controllers for simulation of the whole drive system

is done based on the dynamic models – under validation

- Flight Simulator Evaluation at the end of the project phase II – in 2024







TU Munich: Rotorcraft Simulation Environment





Display configuration

Possible steps after VARI-SPEED II (2024 +)

- (Scaled) models and testing of components





Possible steps after VARI-SPEED II (2024 +)

- Testing of the system







Certification Specifications,

Acceptable Means of Compliance

and Guidance Material

for

Large Rotorcraft

CS-29

(n) Special tests. Each rotor drive system designed to operate at two or more gear ratios must be subjected to special testing for durations necessary to substantiate the safety of the rotor drive system.

Already in the focus:

§ 29.923 (n):

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The project VARI-SPEED II is a transnational research project, funded in Austria by TakeOff (Federal Ministry of Climate Action, Environment, Energy, Mobility, Innovation and Technology) and in Germany by LuFo, the Federal Aviation Research Programme (Federal Ministry for Economic Affairs and Climate Action)

Federal Ministry Republic of Austria Climate Action, Environment, Energy, Mobility, Innovation and Technology





Federal Ministry for Economic Affairs and Climate Action







Thanks for Your Attention !





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