VOITH

Using flexible gears in order to detect the root cause of gear damage

Heidi Götz / Dr. Wolfgang Stamm

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Welcome
to the Next
150 Years

Contents

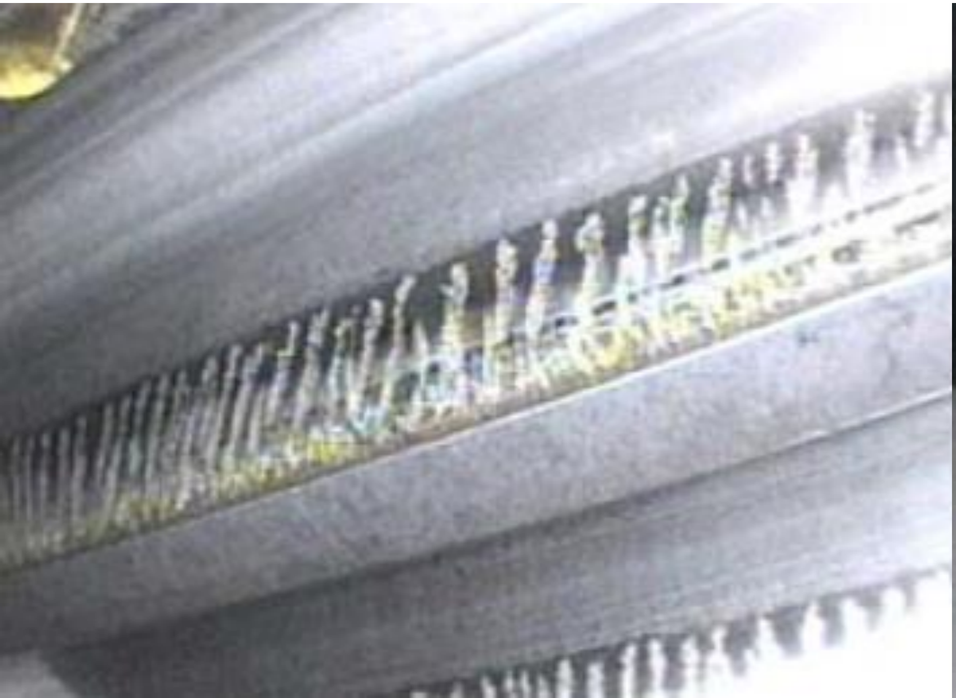
Motivation

VOITH

Damage symptoms

Emergency stop of the Vorecon during running-in

→ Inspection was showing scuffing on all gears (sun, planets and annulus)



Motivation for multibody simulation

- Drive train has stopped
- Such a damage was never seen before
- No idea regarding the root cause

→ Need of simulation

→ Need of a dynamic multibody model

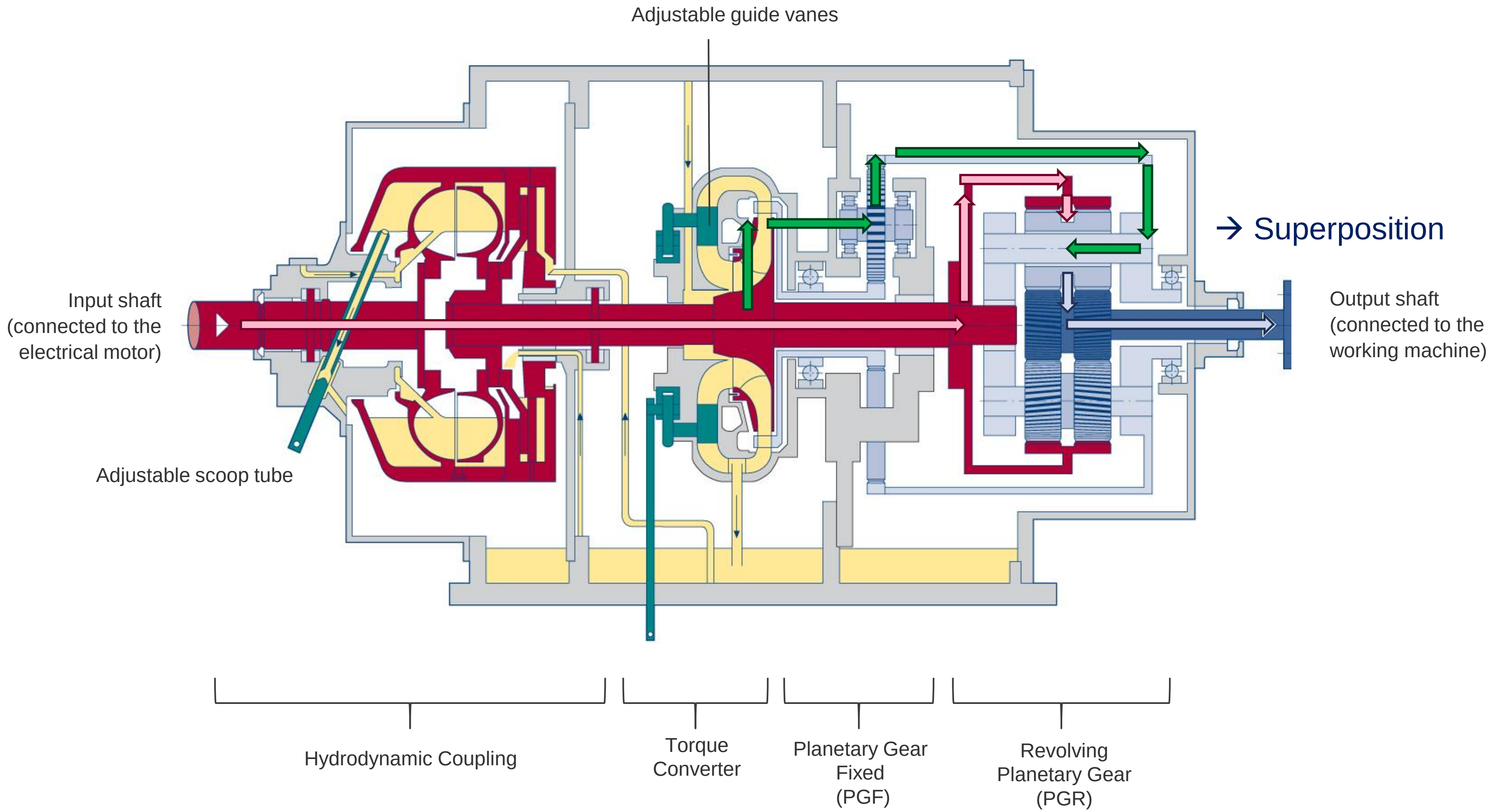
Vorecon – Variable Speed Drives

Description

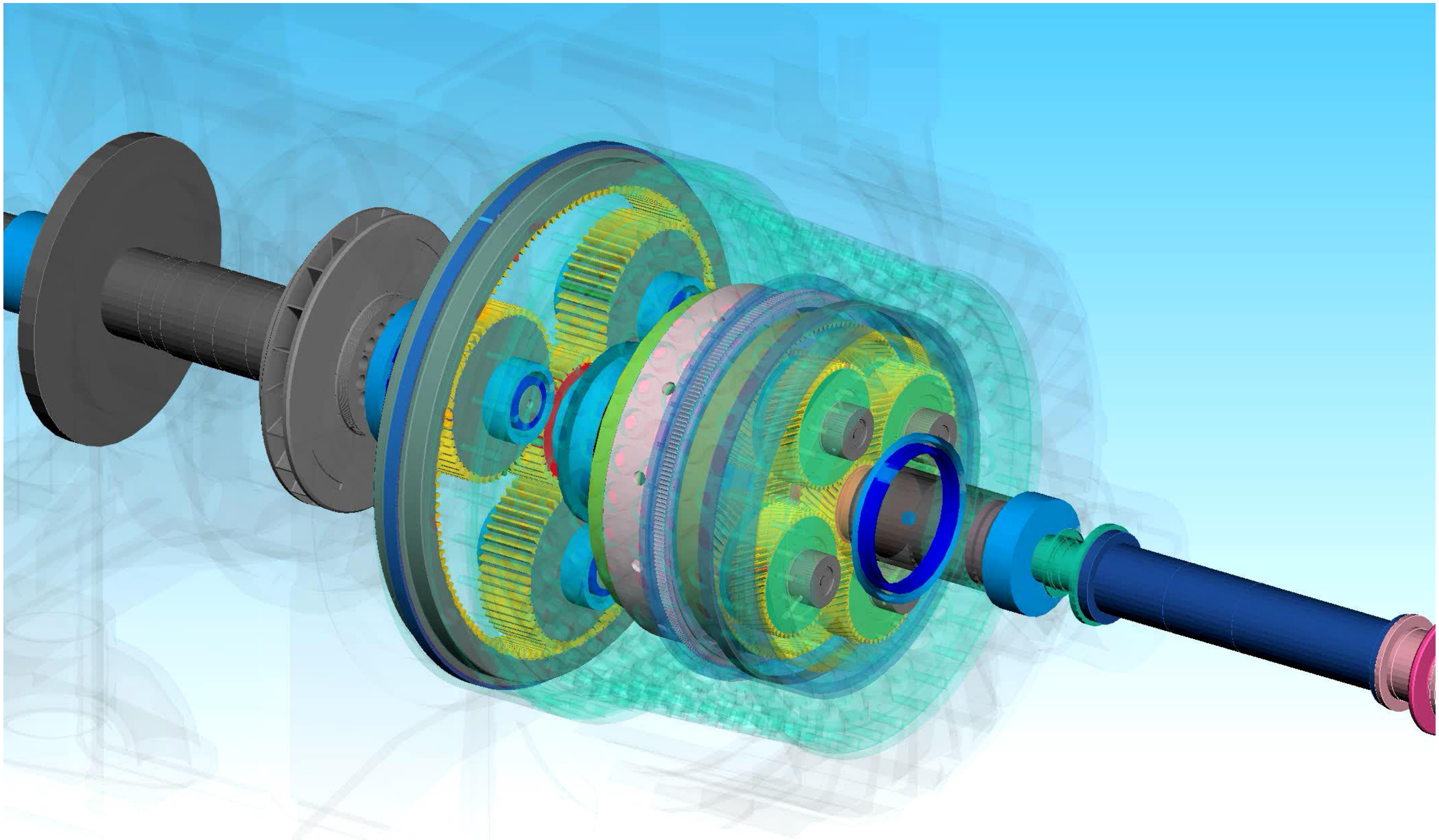
Variable speed hydrodynamic planetary gear

- Boiler feed pumps, blowers, pumps, compressors
- Power up to 50 MW / speed up to 20 000 rpm
- Hydro-dynamic torque converter
- Two planetary gears
- Oil and Gas Industry / Chemical and Petrochemical Industry / Power Generation

Description

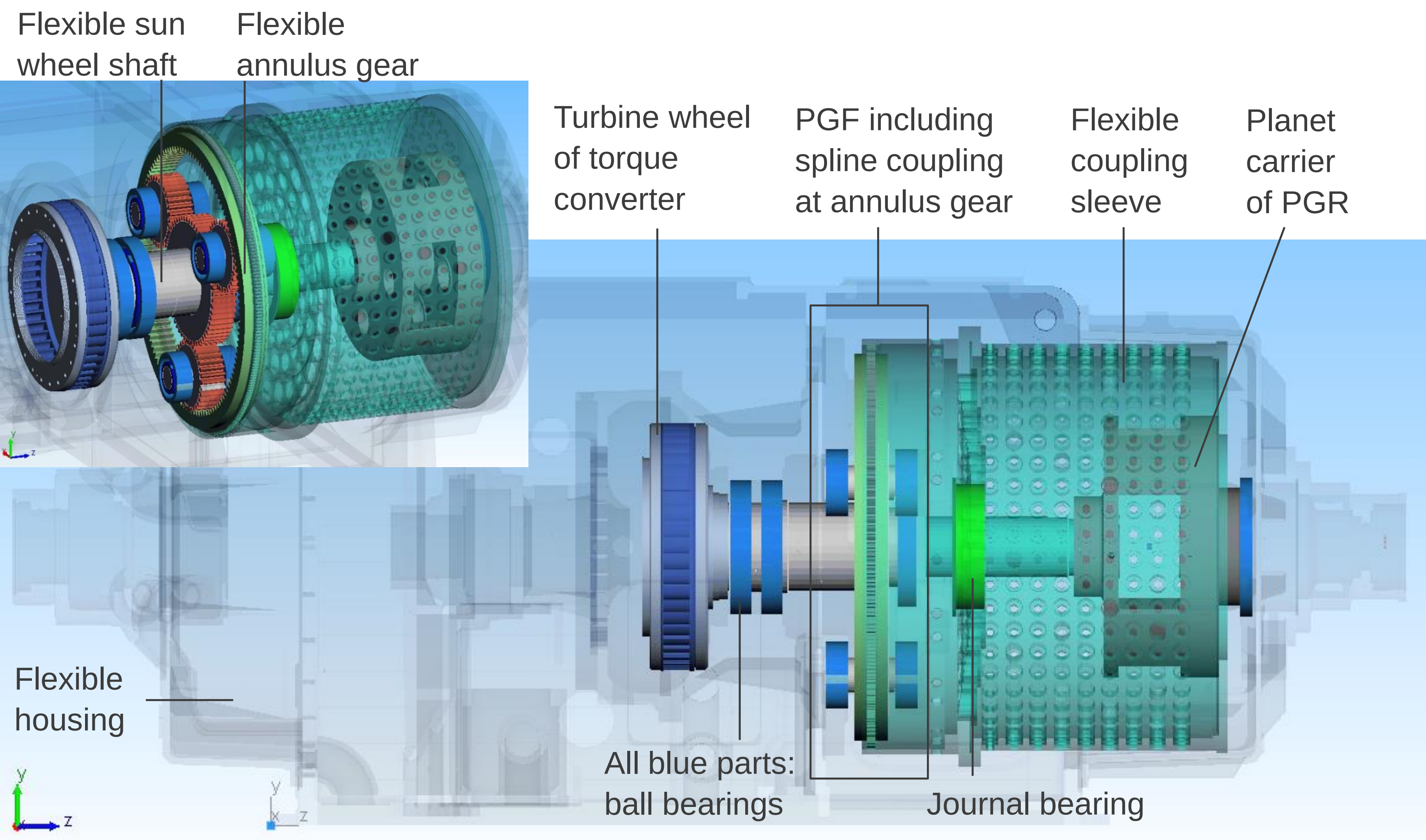


Animation of the SIMPACK-model



Multibody model

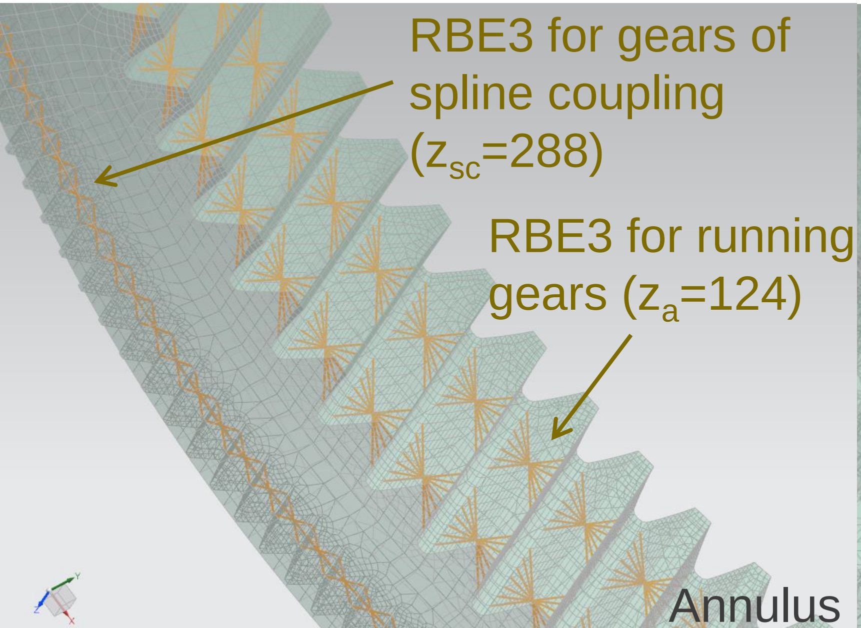
Multibody model

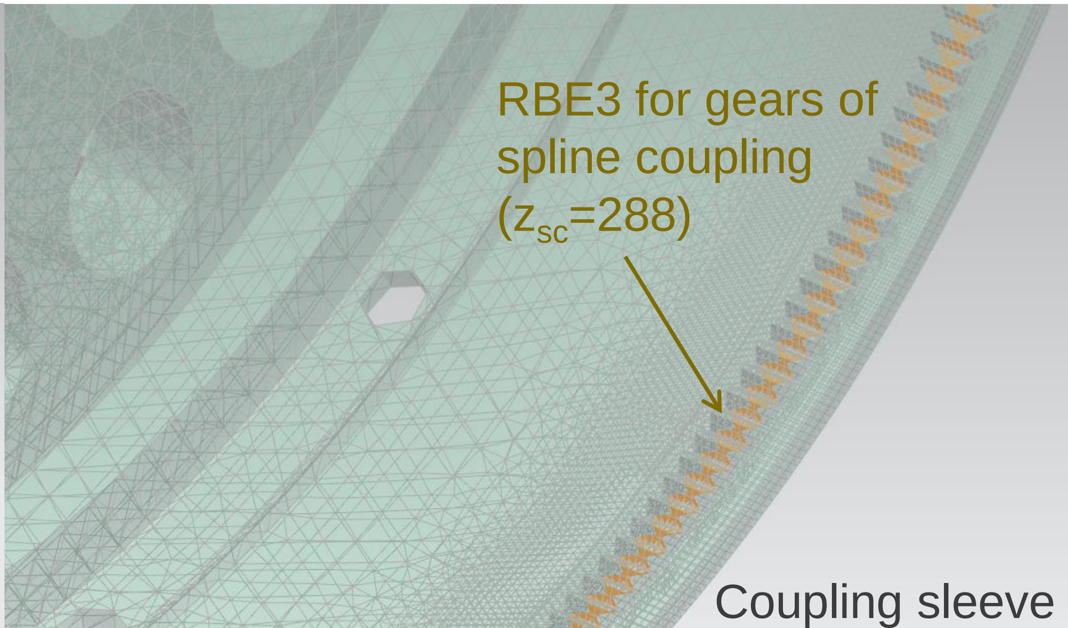


Modelling of elastic gears

SIMPACK *elastic gear pair, method A* was used: „Macroscopic elasticity“ from modal reduction, gear meshing stiffness the same as in rigid gear pair

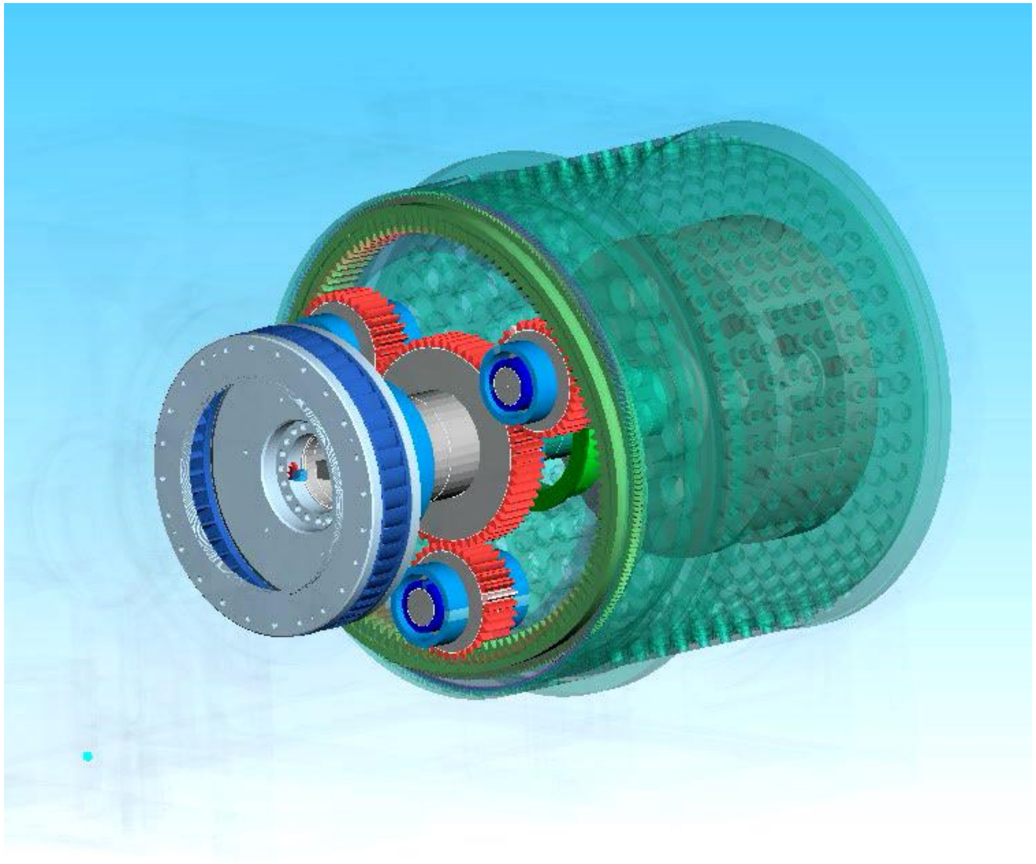
→ New challenges (824 RBE3s; big amounts of data)





Results of simulations

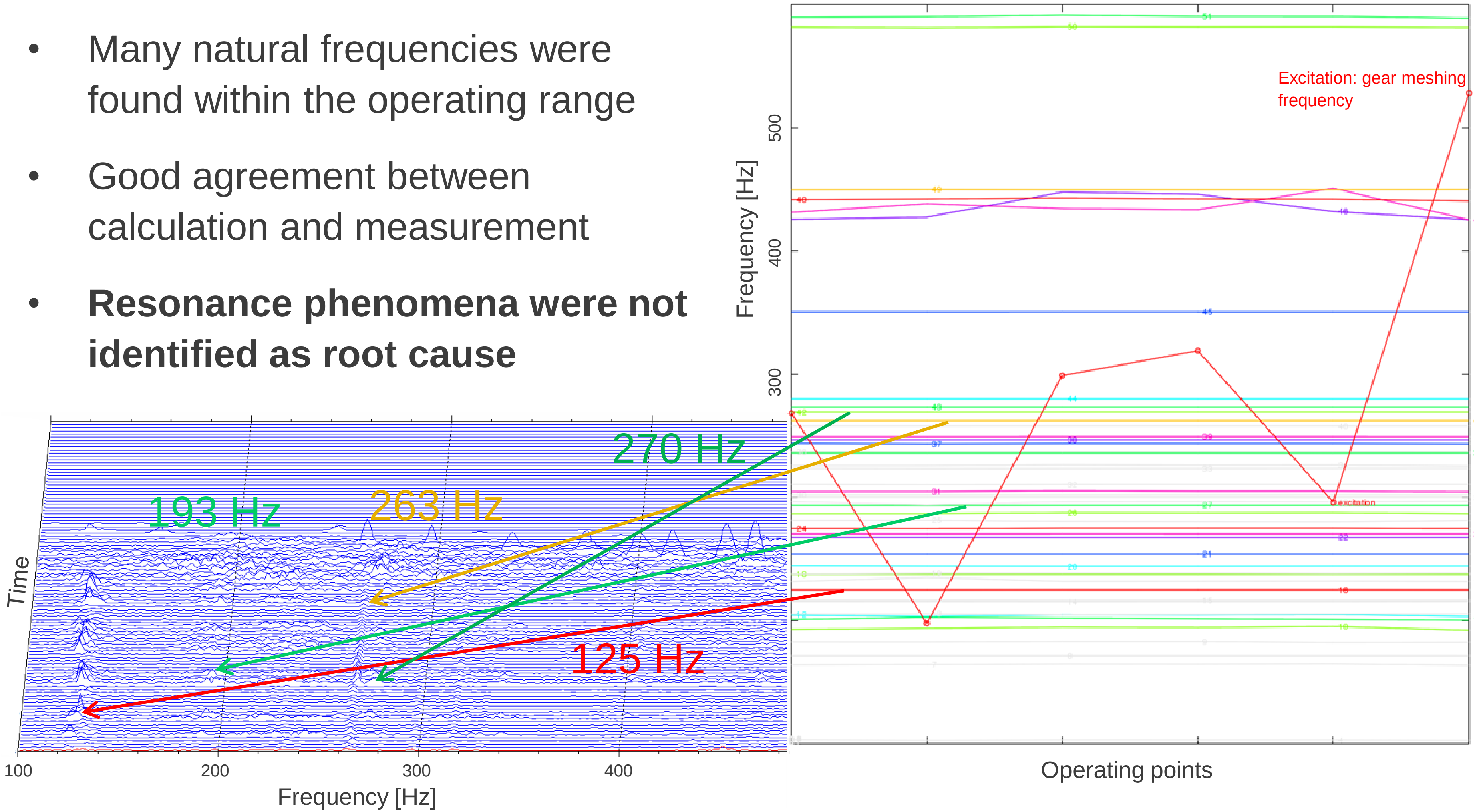
Natural frequencies



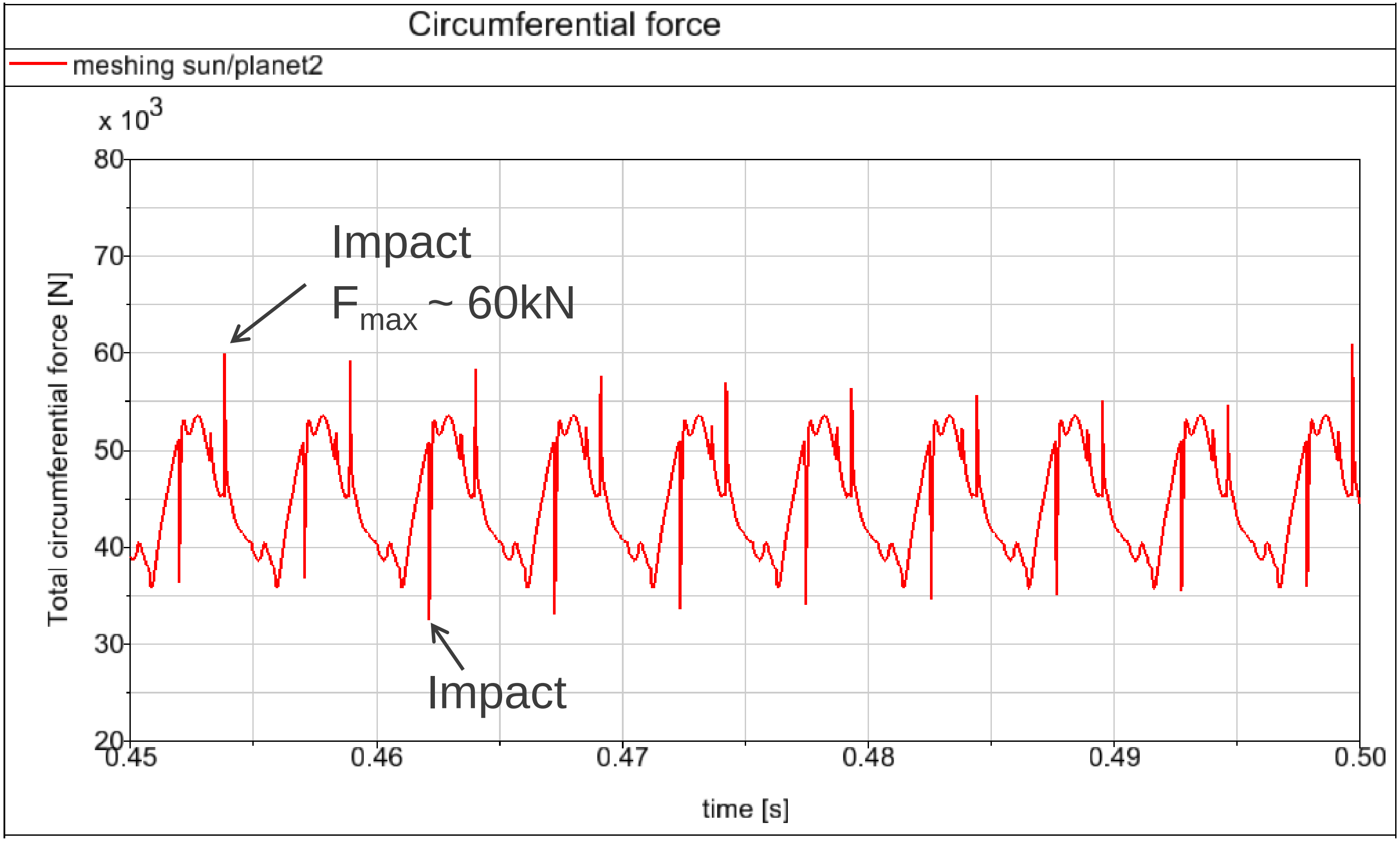
Exemplary natural frequency at 270 Hz

Natural frequencies

- Many natural frequencies were found within the operating range
- Good agreement between calculation and measurement
- **Resonance phenomena were not identified as root cause**

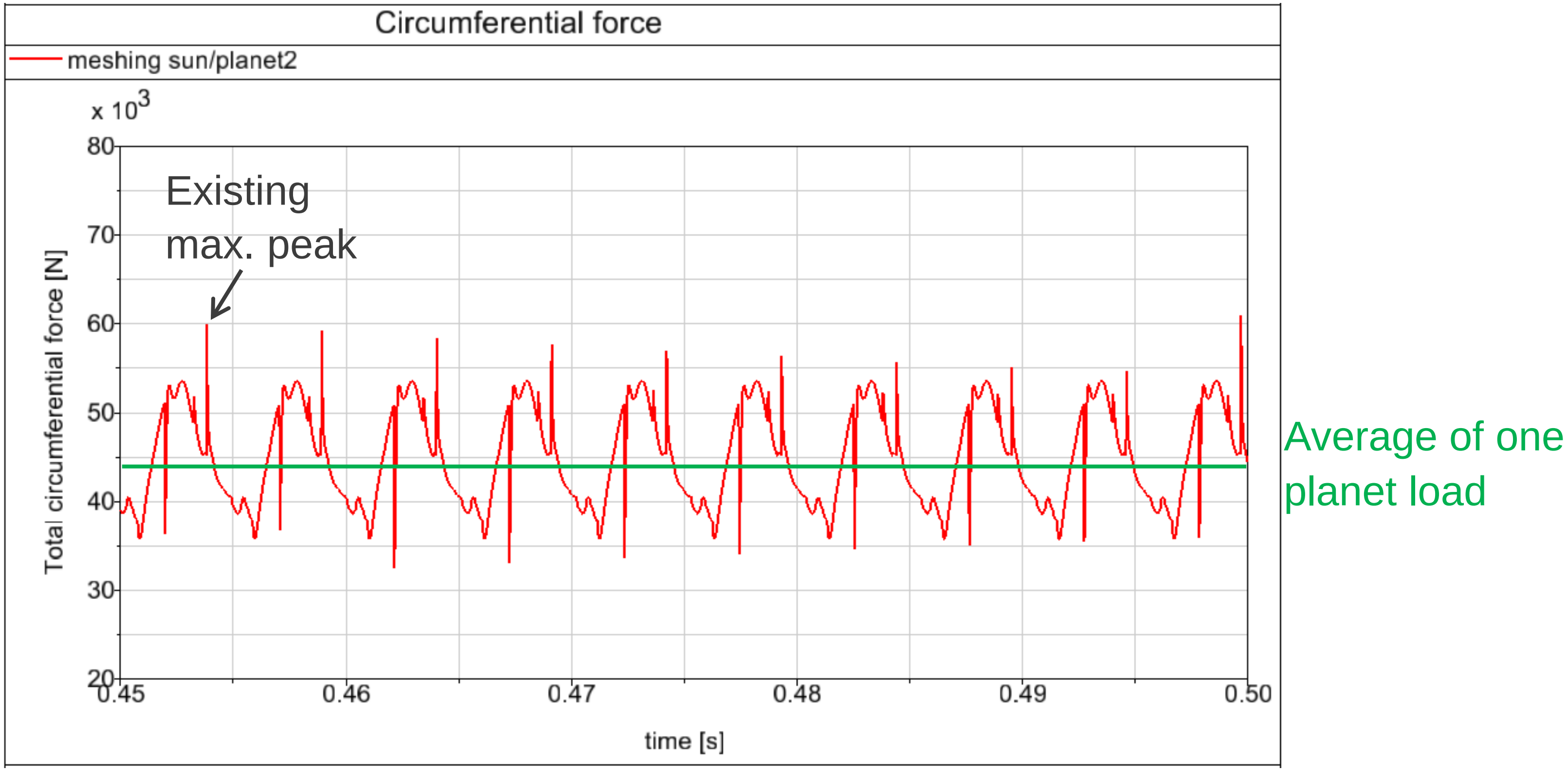


Circumferential forces



Dynamic factor K_V

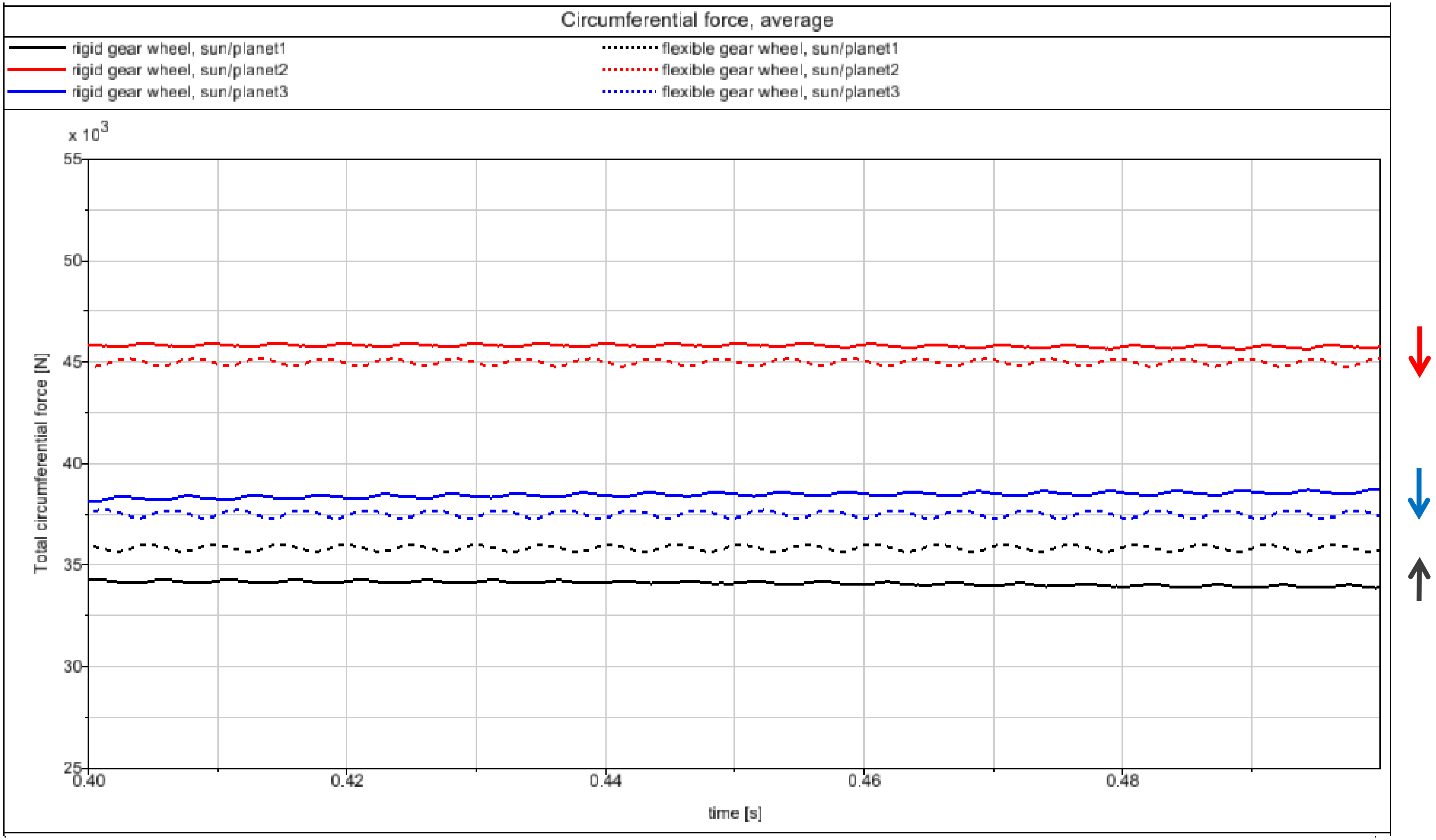
K_V = max. peak / average



Dynamic factor K_V

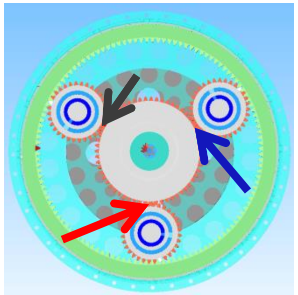
Operating Point	$K_{V\,max}$ [-]			
	Meshing sun/planet		Meshing planet/annulus	
	Rigid	Flexible	Rigid	Flexible
1	1.33	1.22	1.34	1.30
2	1.77	1.32	1.37	1.29
3	1.45	1.59	1.91	1.19
4	1.41	1.48	1.85	1.18
5	1.41	1.41	1.77	1.27
6	1.15	1.22	1.85	1.29
7	1.79	1.13	1.46	1.15
8	1.56	1.20	1.26	1.25
9	1.42	1.52	1.45	1.18

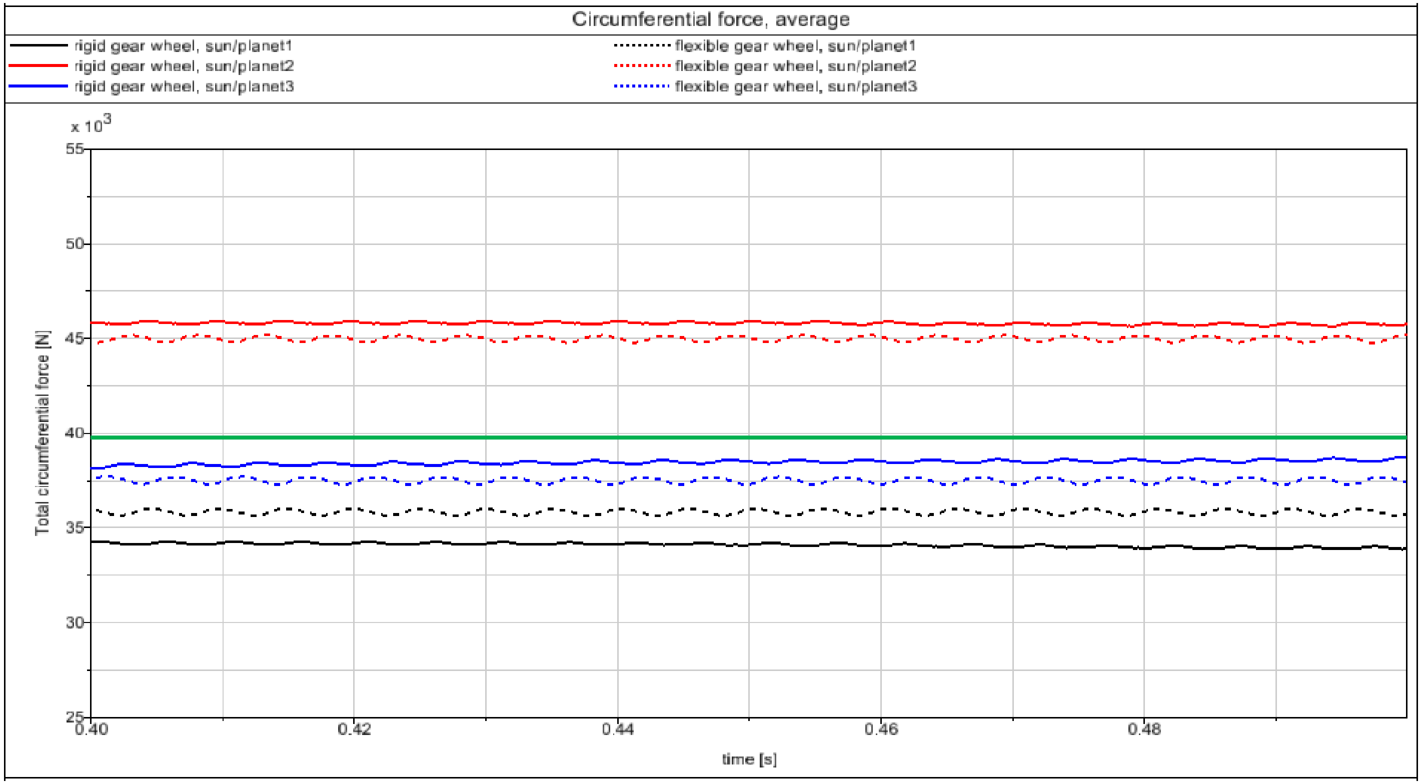
Average of circumferential forces



Load distribution factor K_{gamma}

K_{gamma} = max. planet load / average planet loads





Average of all planet loads

Load distribution factor K_{gamma}

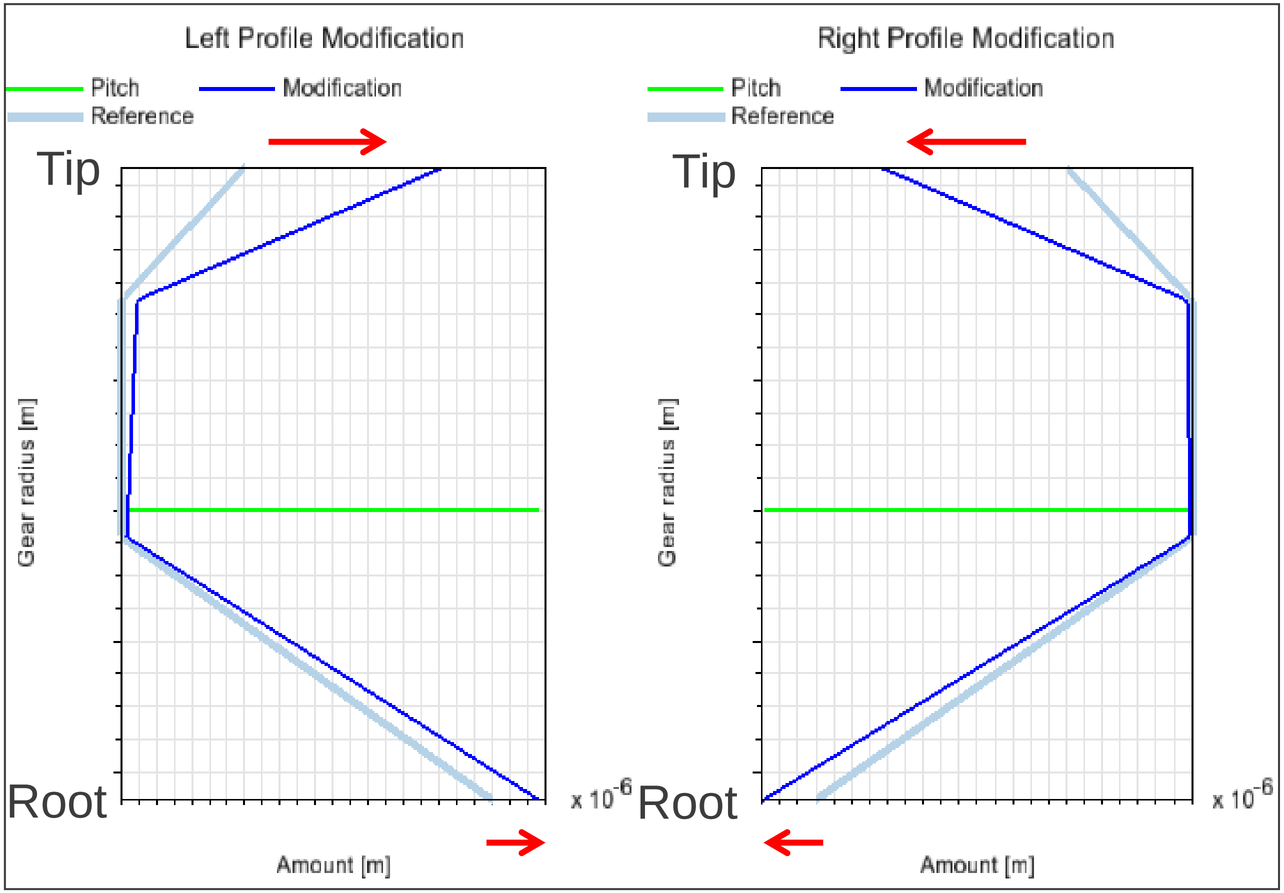
Operating Point	K_{gamma} [-]	
	Rigid	Flexible
1	1.26	1.19
2	1.24	1.15
3	1.15	1.13
4	1.17	1.15
5	1.16	1.13
6	1.3	1.25
7	1.2	1.13
8	1.21	1.15
9	1.21	1.16

Summary

- K_V and K_{gamma} values were higher than expected from design
- With the help of flexible gears the dynamic behavior seems to be closer to reality
- **Impacts were identified as root cause**

→ Now: possible to search for a suitable corrective measure in accordance with the results

Derived corrective measure



Modifying the existing tooth profile modifications of the planet gears:

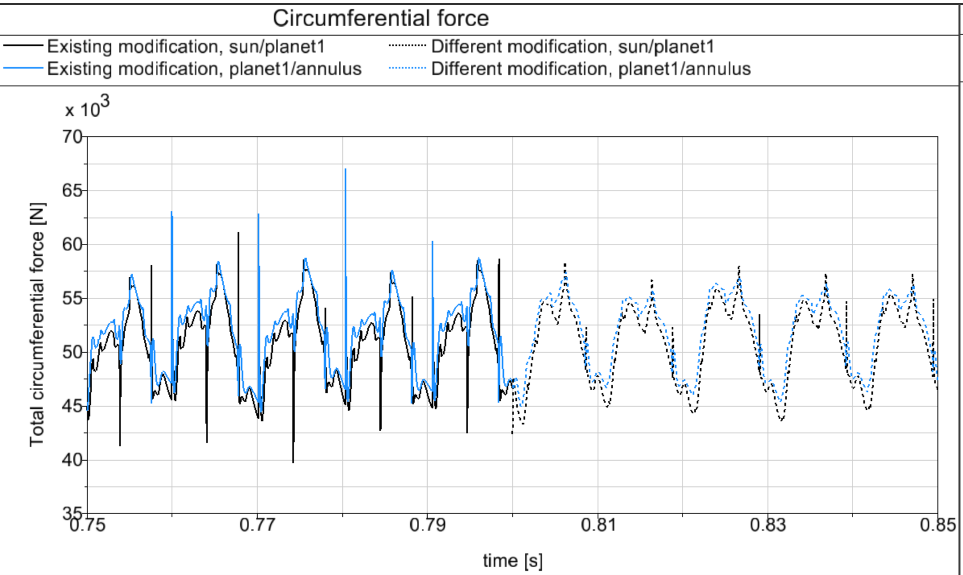
- Tip modification
- Root modification

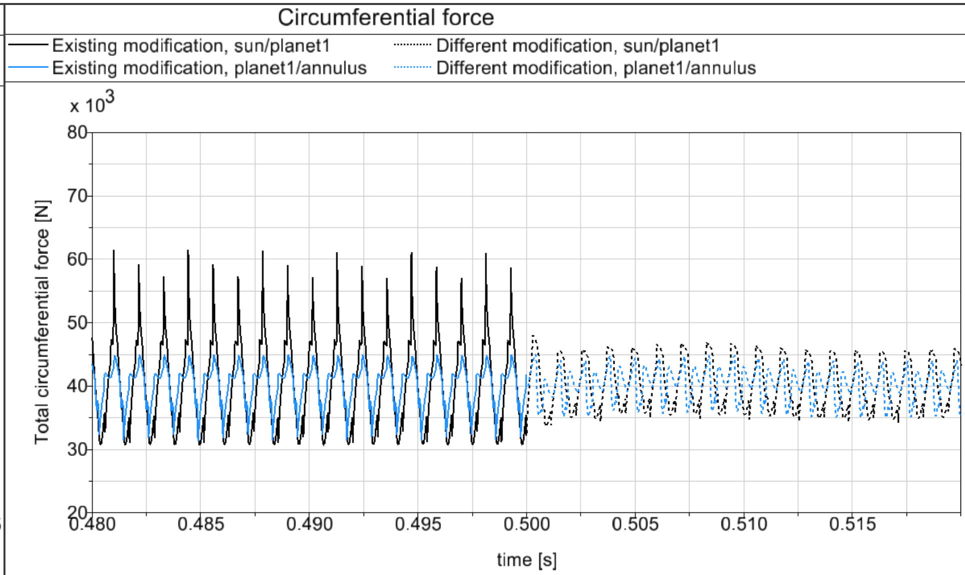
existing mod.

new mod.

Results of corrective measure

- Impacts were reduced (in both meshing transitions)
- Amplitudes were reduced
- Corrective measure led to an improvement for almost all required operating points

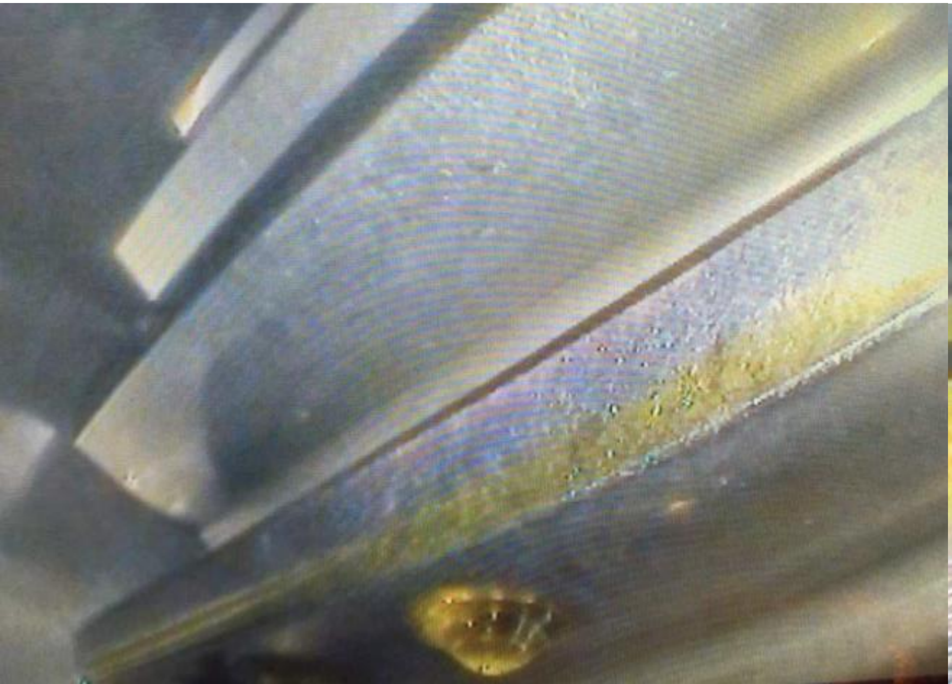




Results of technical implementation

New borescope inspection

No scuffing anymore



Summary

- Using **flexible gears** could show us the root cause for the damage
- Differences were identified to the results with rigid gears
- Were able to determine a suitable corrective measure for a dynamic system
- Technical implementation of the corrective measure led to a **success** regarding scuffing

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Contact:
Heidi Götz
Simulation Engineer
Tel. +49 7951 32-427
heidi.goetz@voith.com

Dr. Wolfgang Stamm
Centers of Competence
Tel. +49 7951 32-1711
wolfgang.stamm@voith.com

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