GREEN-LOOP

Sustainability and Environmental Benefits for Wood Composite Applications

4th internal Workshop, 21st February 2025

Funded by the European Union

This project has received funding from the European Union's Horizon Europe, grant number 101057765. UK Participants in Horizon Europe Project GREENLOOP are supported by the UK Research and Innovation (UKRI) under the UK government's Horizon Europe funding guarantee, grant number 10038028.

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Agenda

1. Introduction
2. Overview and discussion of wood composite production and properties – identification of opportunities and risks *(60 min)*
3. Applicability of the materials for bearings – performance, design (30 min)
4. Ideas for components suitable to be manufactured with wood composites (*30 min)*
5. Summary: Ideas for future actions of exploitation of project results (*20 min)*

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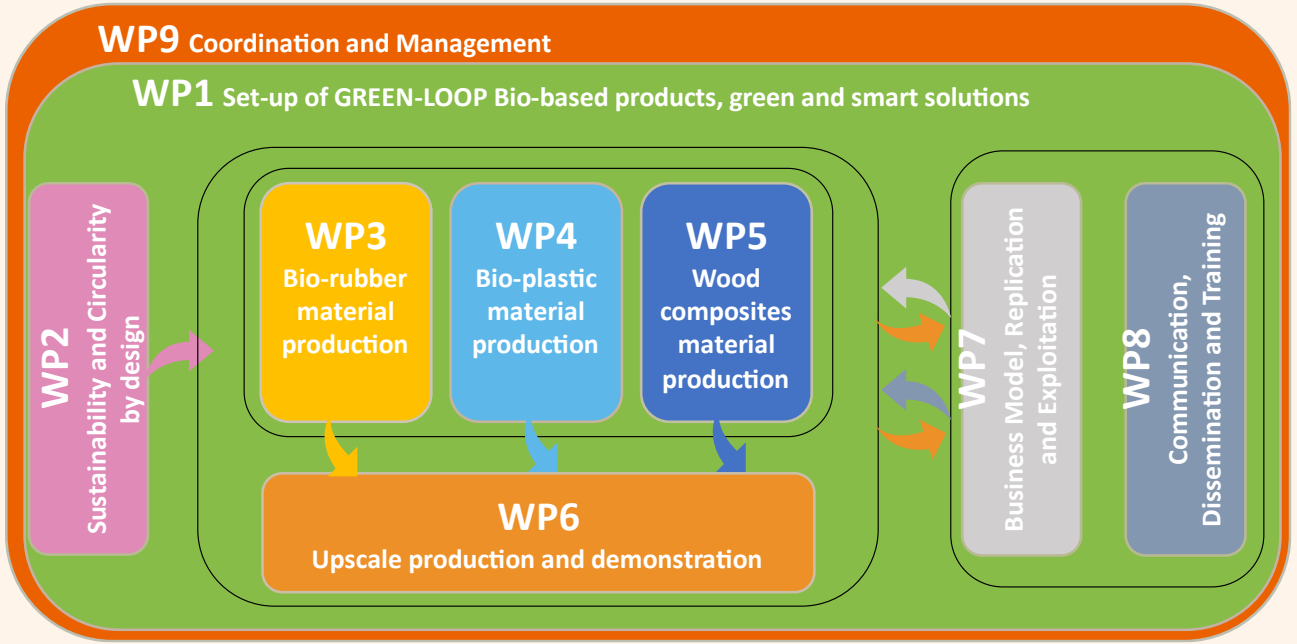

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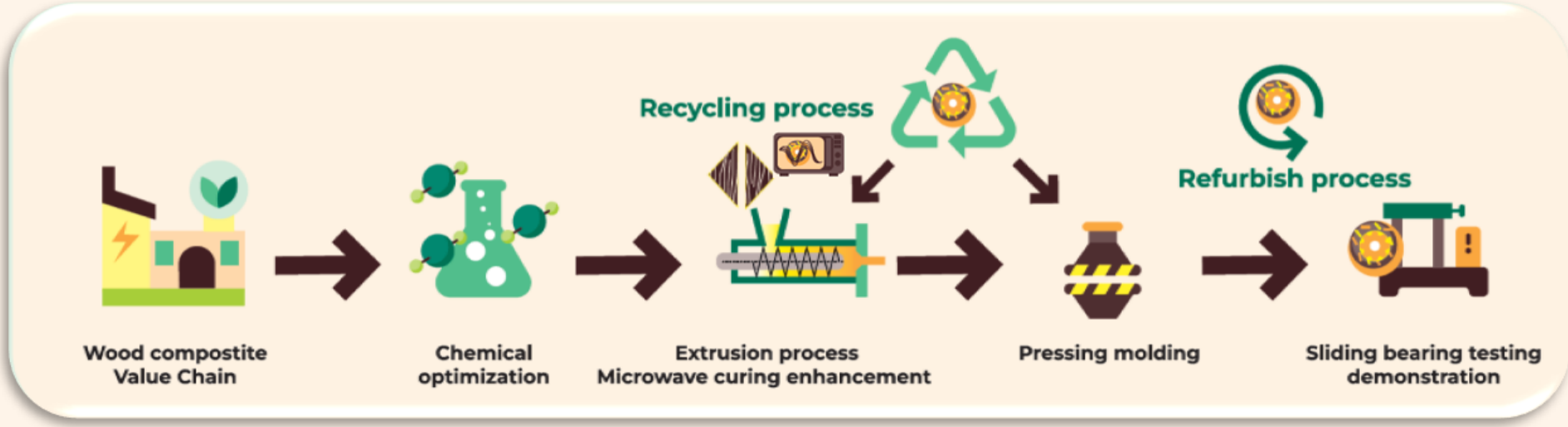
Wood composites material production

Flow Chart



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WP5 – Progress summary

Successfully completed

1. Specifications have been defined for slide bearings
2. Materials development and process successful
3. Microwave enhancement successful
4. Design of tooling and bearings completed
5. Minor concerns on material homogeneity and tensile strength
6. Very promising friction and wear performance

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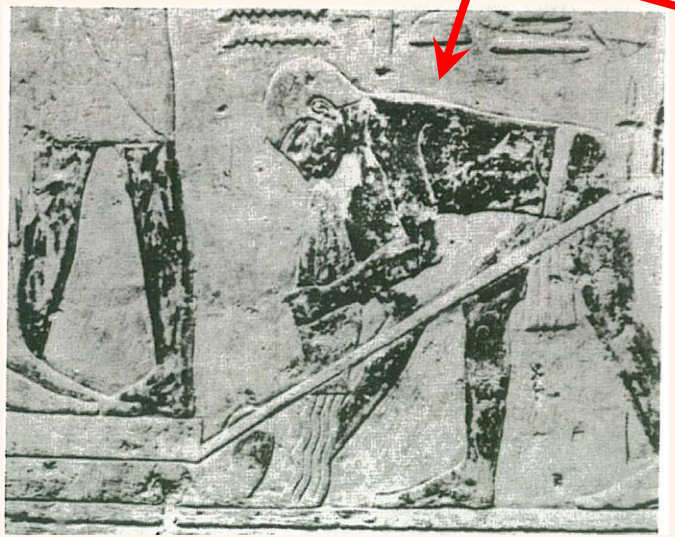
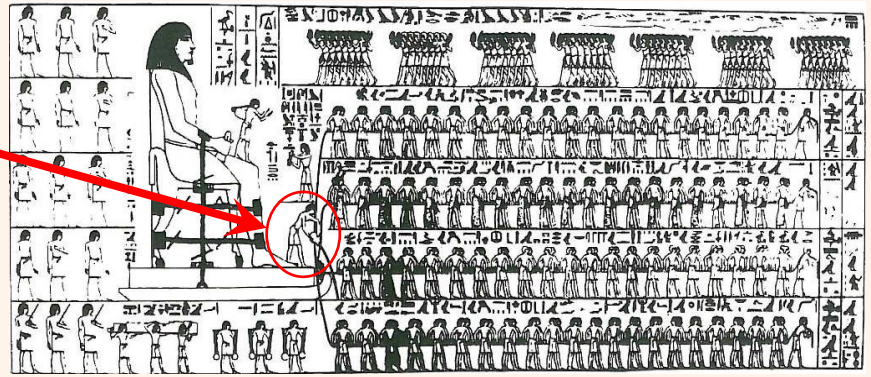
Tribology

Tribologist





- 3500 bis 30 v. Chr., Sumerers and egypts
- 1452-1519 Leonardo da Vinci
- 1663-1705 Guillaume Amontons $F_T = \mu \cdot F_N$
- 1683-1744 John Theophilius Desaguliers
- 1707-1783 Leonhard Euler
- 1736-1806 Charles Augustin Coulomb

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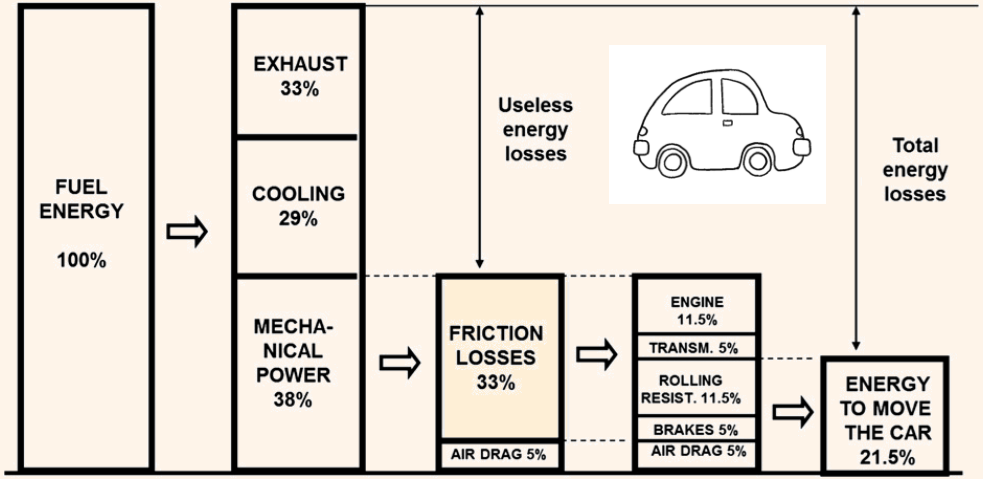
Tribology

Friction: Inhibition of movement between solids and particles
Wear: Loss of material on surfaces due to mechanical causes (i.e. friction)
Tribology: research field of interacting surfaces in relative motion



Global energy consumption due to friction in passenger cars - ScienceDirect

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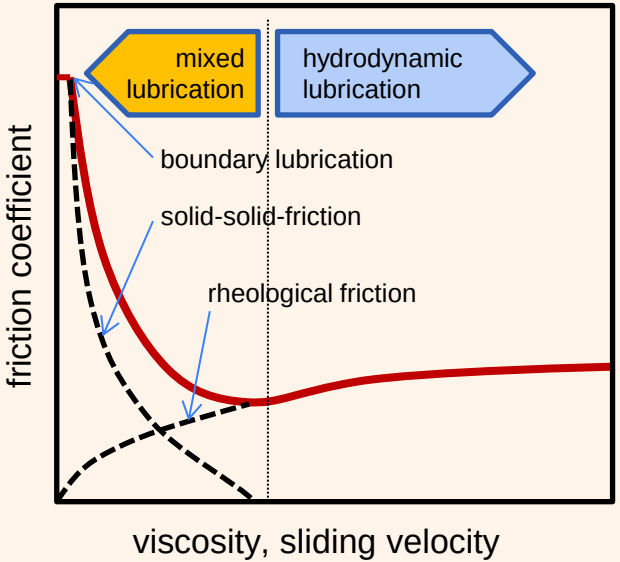
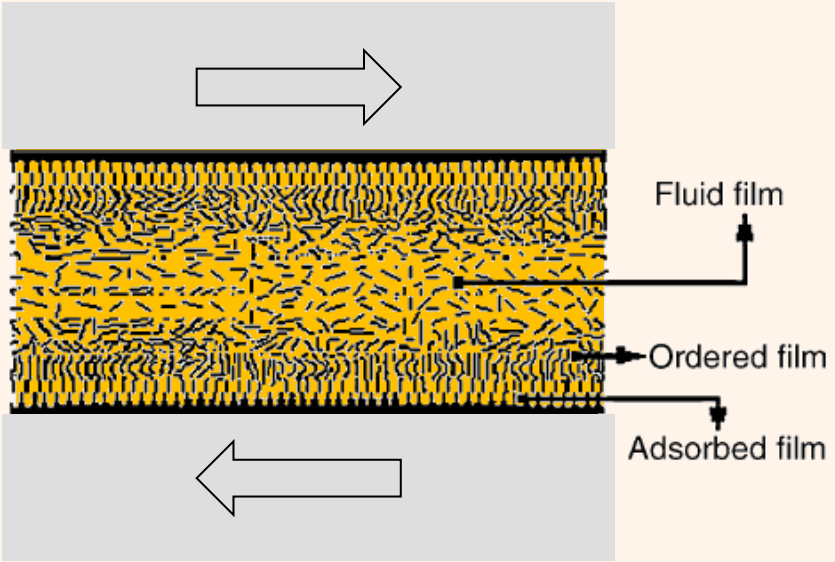
Tribology – Lubricated Friction





Tribologie-Handbuch: Tribometrie, Tribomaterialien, Tribotechnik | SpringerLink

Thin Film Lubrication | SpringerLink

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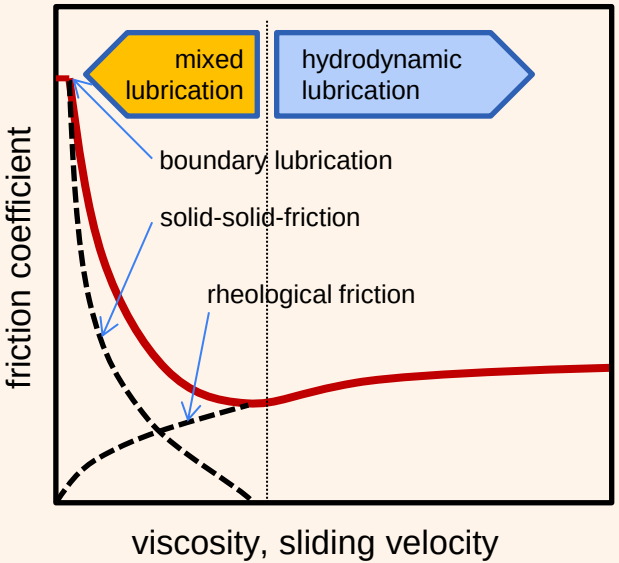
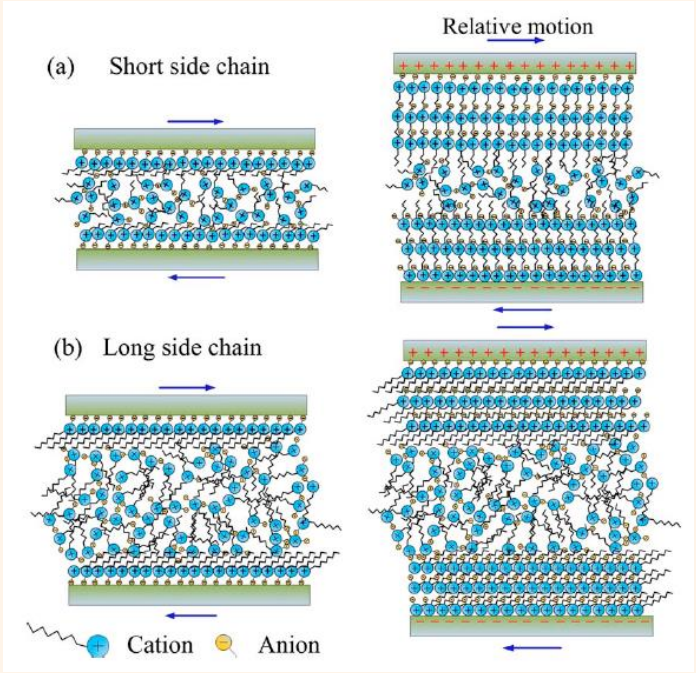
Tribology – Lubricated Friction



[Tribologie-Handbuch: Tribometrie, Tribomaterialien, Tribotechnik | SpringerLink]



[Nanoconfined ionic liquids under electric fields | Applied Physics Letters | AIP Publishing]

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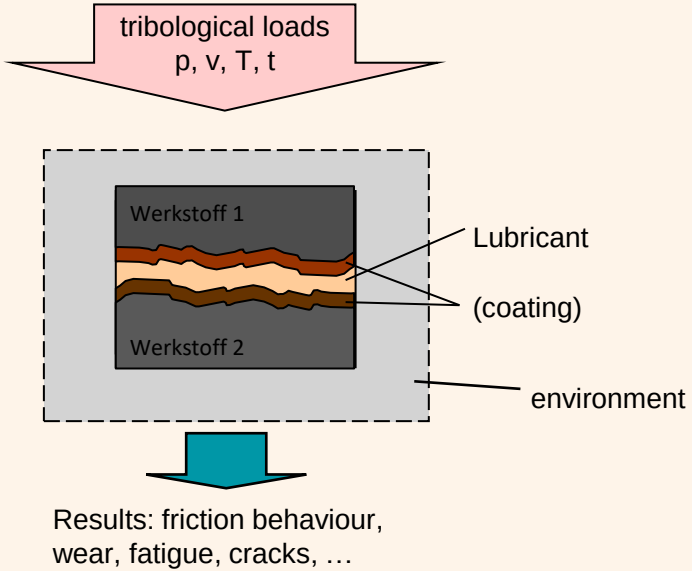
Tribology – System

The tribological system: All material components involved in a tribological load and their properties with the resulting changes.

Variables
The processes and variables characteristic of the load
System structure: All material components
Stress collective: Stress variables

Why do I need this system?
OR
What do I want to improve about it?



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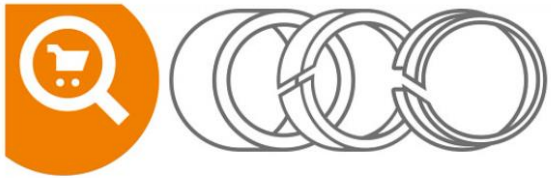
State of the Art: Polymer Composites

Maintenance-free iglidur® plain bearings made of plastic

Bearings serve to prevent direct contact, e.g. between shaft and mount, so that they do not wear out. Most bearings must be lubricated regularly to ensure fault-free function. iglidur® plain bearings do not require any additional lubricants. They are therefore maintenance-free and represent a cost-effective alternative to metal plain bearings. They are available in various types and in more than 10,000 sizes, here in our online bearing shop. The iglidur® materials specially developed by igus® enable a wide range of applications for our plain bushings in various industries. For example, for use at high temperatures, in contact with food or chemicals and under high loads.

What you will find on this page

- Free sample box ▼
- iglidur® bearing stroke & online shop ▼
- Free white paper ▼
- Plain bearing wiki ▼
- Special designs and drawing parts ▼
- Online tools for plain bearings ▼



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Requirements for Tribological Applications

Wood-composite materials specifications definition

Product	Wood Composites	
Mechanical Properties	**Value**	**Units**
Compressive strength	> 70 MPa	
Tribological Properties	**Value**	**Units**
Wear Coefficient	**< 10^{-5} $mm^3/(Nm)$**	
Friction coefficient	**< 0.3 under dry sliding**	
pv-value	**> 0.3**	**MPa · m/s**
Working conditions	**Value**	**Units**
Temperature	0 - 100	°C

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Materials Overview

- Biopolymer Mix
- Wood Fibers size < 1 mm
- Fillers (Fibers)/ additives

Batch 1	Batch 2	Batch 3
12 Materials	7 Materials	12 Materials
Biopolymer Mix 1	Biopolymer Mix 2	Biopolymer Mix 2
+ Graphite	+ Wood Fibres	+ Wood Fibres
	+ Recycled Glass Fibres	+ Recycled Glass Fibres
	+ Lignin	+ Lignin

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Materials Development

A total of 15 materials from development Batch 3 were received during this period. Composites based on wood and glass fibres

- Microstructure
- Density
- Hardness
- Thermal analysis
- Thermogravimetrical analysis TGA
- FTIR analysis
- NDT Computer Tomography
- Compressive Strength

Material	Composition
V263	Bio-polymer T2241X / Wood fibre C400 / 10% Glass short fibre 3 mm
V261	Bio-polymer T2241X / Wood fibre C400 / 20% Glass short fibre 3 mm
V259	Bio-polymer T2241X / Wood fibre C400 / 30% Glass short fibre 3 mm (Like V237)
V237	Bio-polymer T 2241X / Wood fibre C400 / Glass short fibre 3 mm
V265	Bio-polymer T2241X / Wood fibre C400 / 10% Glass short fibre powder
V267	Bio-polymer T2241X / Wood fibre C400 / 20% Glass short fibre powder
V269	Bio-polymer T2241X / Wood fibre C400 / 30% Glass short fibre powder
V271	Bio-polymer T2241X / Wood fibre C400 / 30% Glass short fibre powder (Like V244)
V244	Bio-polymer T 2241X / Wood fibre C400 / Glass fibre (FG400/100)
V273	Bio-polymer T2241X / Wood fibre C400 / 30% Glass fibre (FG400/100) / 10% Lignin
V240	Bio-polymer T 2241X / Wood fibre C400 / Lignin 2
V275	Bio-polymer T2241V / Wood fibre C400
V277	Bio-polymer T2241V / Wood fibre C400 / 30% Glass short fibre powder
V279	Bio-polymer T2241X / Wood fibre B60
V281	Bio-polymer T2241X / Wood fibre B60 / 30% Glass short fibre 3 mm

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Materials Processing

- Successful WC manufacturing with the MW prototype

V300 MW

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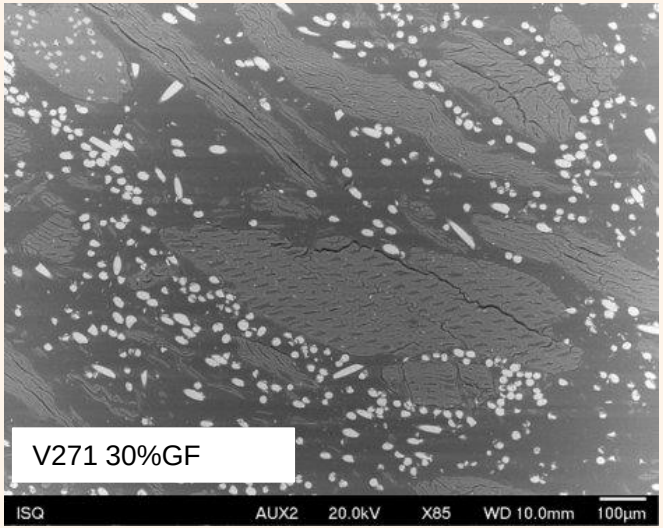
Microstructure

Microstructure

- Partially agglomeration of GF at higher contents
- Defects: Decohesion between matrix and GF and between matrix and wood fibres. Not critical.
- Preorientation of wood fibres (?)



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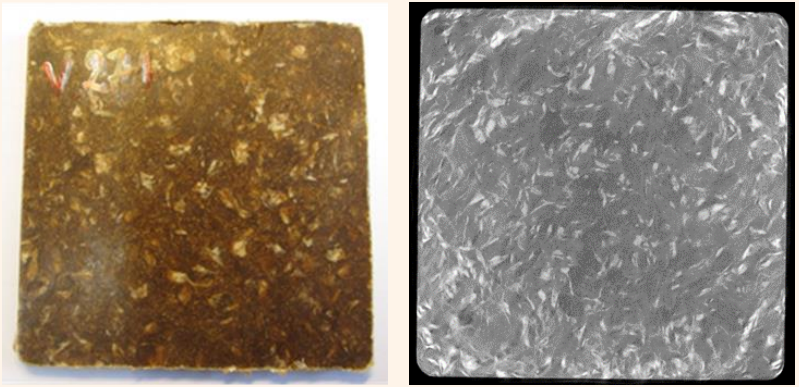
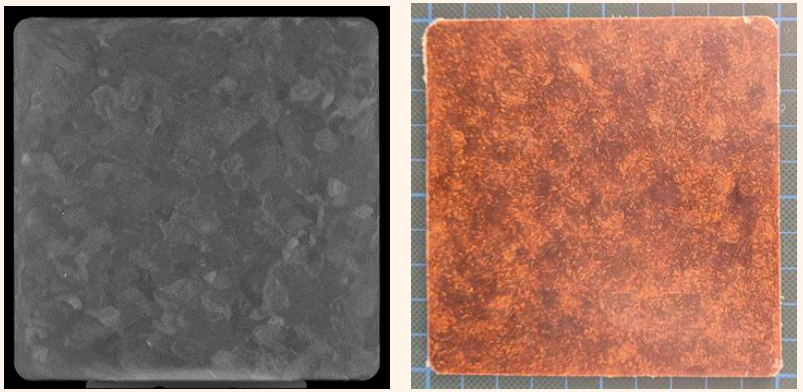
Materials Processing

- Successful implementation of microwave enhancement → improved homogeneity and material properties → reduced energy consumption

V271



V300 MW



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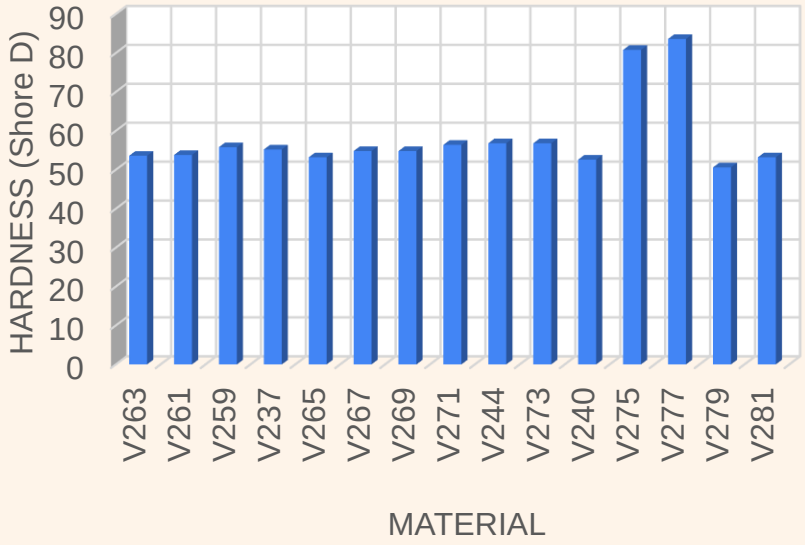
Properties

Properties

- Hardness values: > 50 Shore D
- Density: ca. 1.2 g/cm³
- Compressive strength: > 60 MPa
- Compressive strength with MW enh.: 82 MPa
- Thermal stability: 120 °C (DTA)
- Tensile Strength: average 8 MPa
- Tensile Strain: average 2 %



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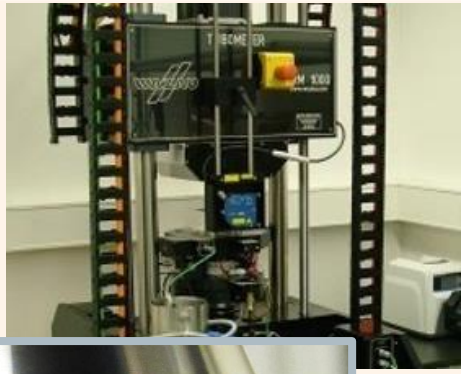
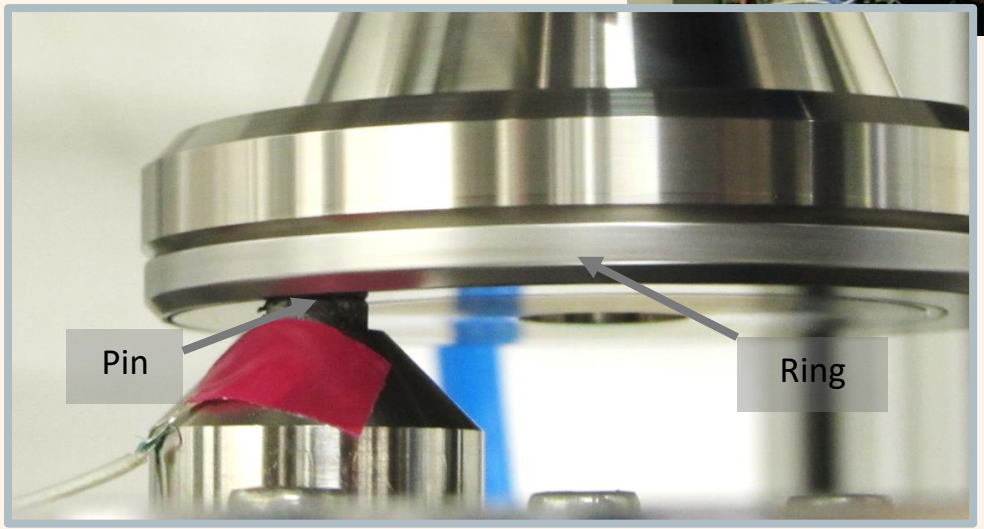
Tribological Testing (Model Scale)



Test parameters :

- Normal force: 85 N ≙ 3 MPa
- Velocity: 0,1 m/s
- PV: 0,3 MPa * m/s
- Test duration: ca. 6 h
- Test media: dry, Air at RT
- Samples: Pins diam 6 mm, height >3mm



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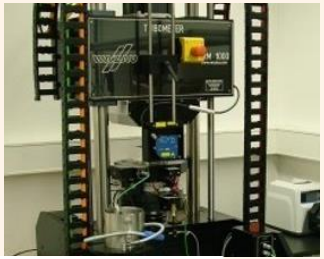
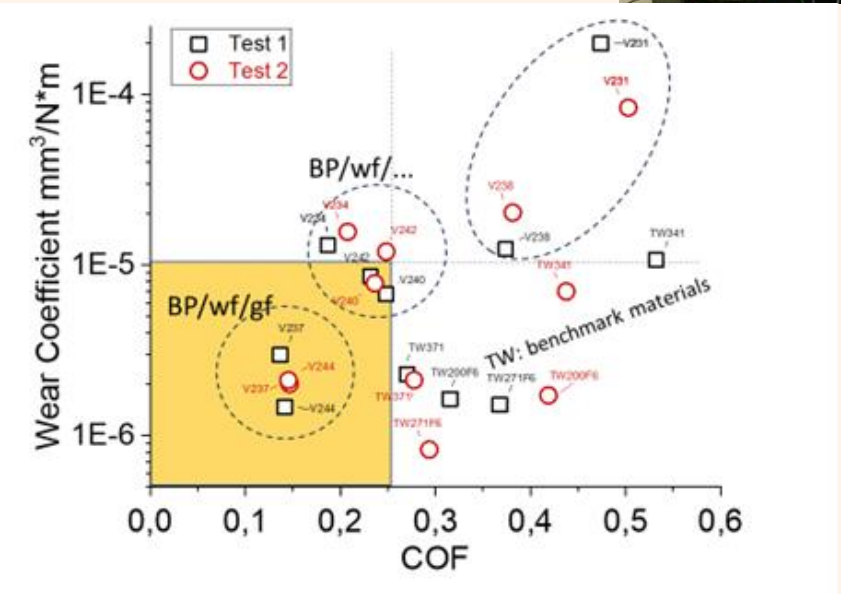
Results of Model Tests



Overview of friction and wear results of batch 2 materials

➔ *Very good results for two material types*



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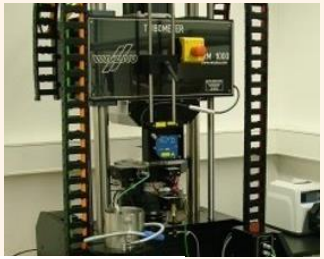
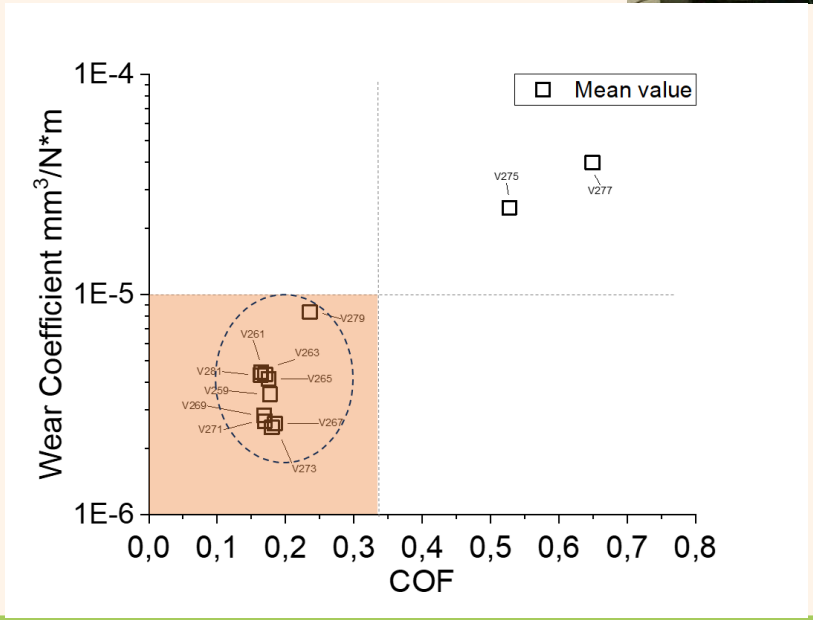


Overview of friction and wear results of batch 3 materials

➔ *Very good wear properties confirmed and materials selected*



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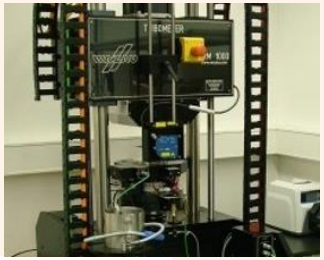

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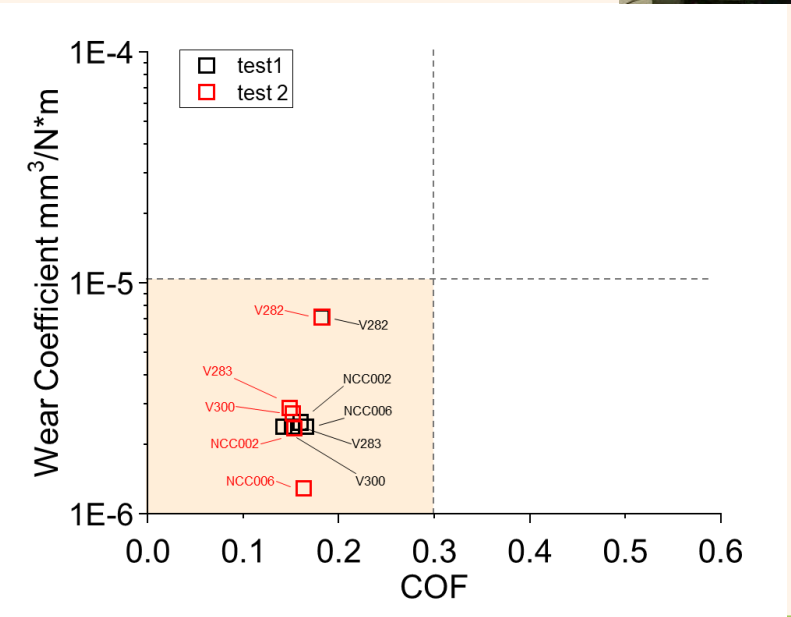

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Bearing Design (general)

Juli 1998

Gleitlager Teil 6: Buchsen aus Thermoplasten	DIN 1850-6

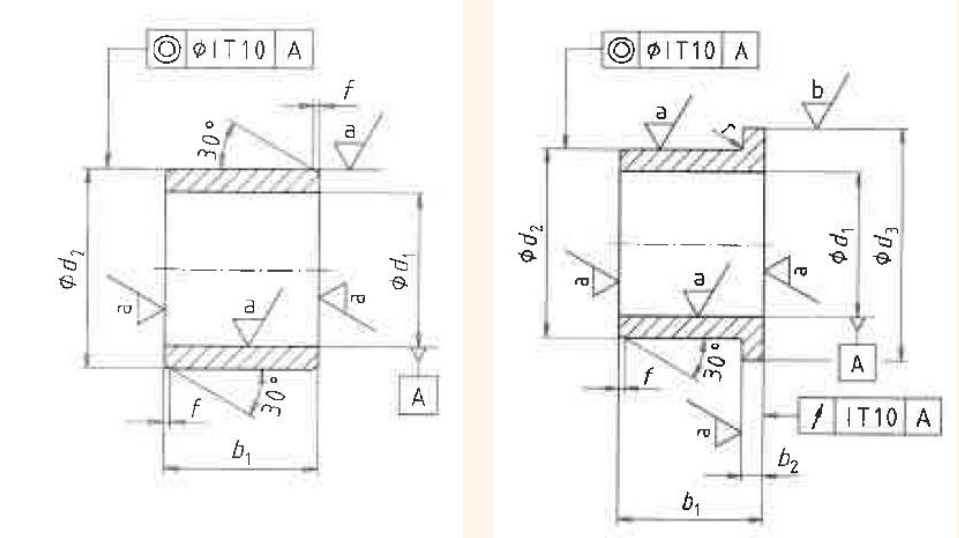

Tabelle 1: Nennmaße und Grenzabmaße

d_1	d_2			d_3	b_1			b_2	f	r
Nennmaß	Nennmaß	Grenzabmaße für Toleranzgruppe A	B	d13	h13			h13	max.	≈
6	12	+0,21 +0,07	zb11	14	6	10	—	3	0,5	0,3
8	14			18	6	10	—	3	0,5	0,3
10	16	+0,27 +0,09		20	6	10	—	3	0,5	0,3
12	18			22	10	15	20	3	0,8	0,5
14	20			25	10	15	20	3	0,8	0,5
15	21	+0,33 +0,11		27	10	15	20	3	0,8	0,5
16	22			28	12	15	20	3	0,8	0,5
18	24			30	12	20	30	3	0,8	0,5
20	26	+0,45 +0,15		32	15	20	30	3	0,8	0,5
22	28			34	15	20	30	3	0,8	0,5
(24)	30			36	15	20	30	3	0,8	0,5
25	32			38	20	30	40	4	0,8	0,5
(27)	34	+0,60 +0,20		40	20	30	40	4	0,8	0,5
28	36			42	20	30	40	4	0,8	0,5
30	38			44	20	30	40	4	0,8	0,5
32	40			46	20	30	40	4	1,2	0,8
(33)	42			48	20	30	40	5	1,2	0,8

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Bearing Designs and Testing

Tests with real bearing configurations

- load (radial force): 10 - 650 N
- rotational speed: 0 - 3000 rpm
- temperature: RT - 100 °C
- size: 2 - 16 mm ($Ø_{innen}$)
- lubrication: unlubricated, grease, oil

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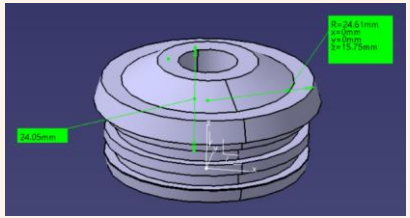
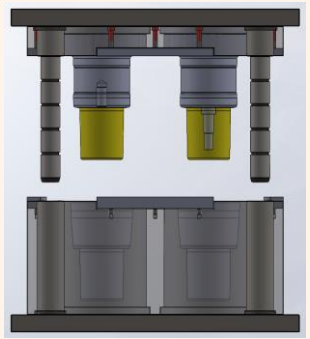
Bearing Designs and Testing

- Bearing design finalised – bearing within a conveyor roller
- Flat panels produced for use in tribological testing
- Tooling produced for final bearing production
    - Delivered in M23
    - First trials completed with new tooling to take learning into WP6



Bearing design

Test piece



Tooling

Bearing blank

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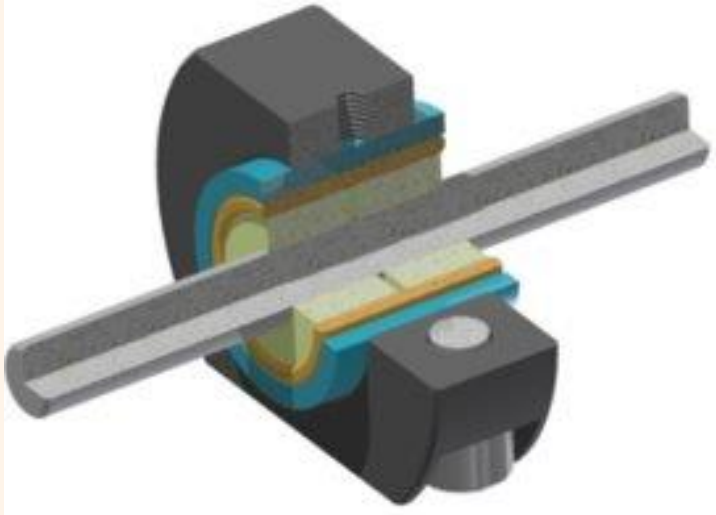
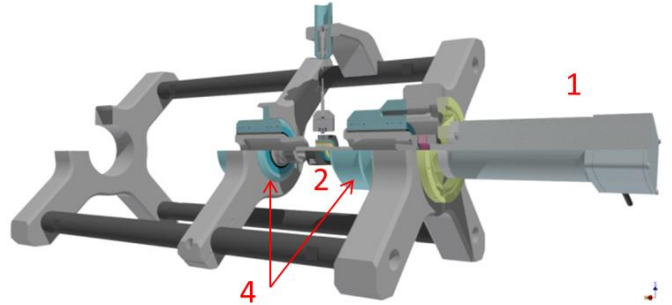
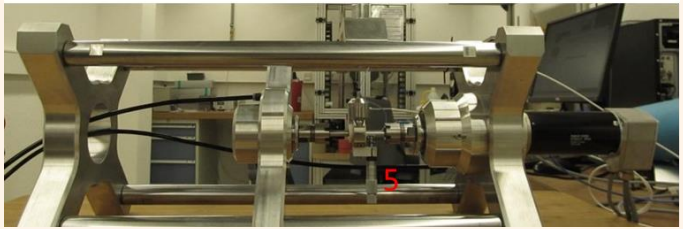
Bearing Designs and Testing

Tests with real bearing configurations







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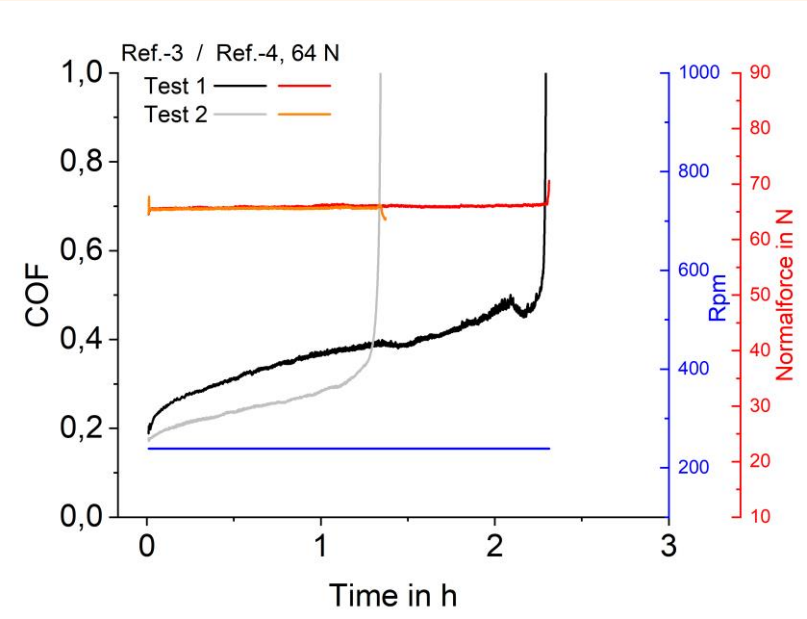
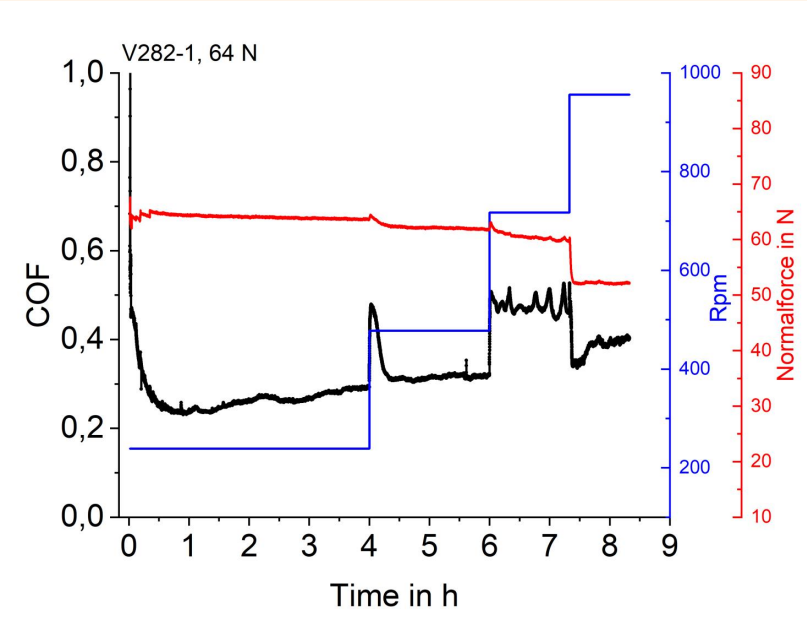
Results





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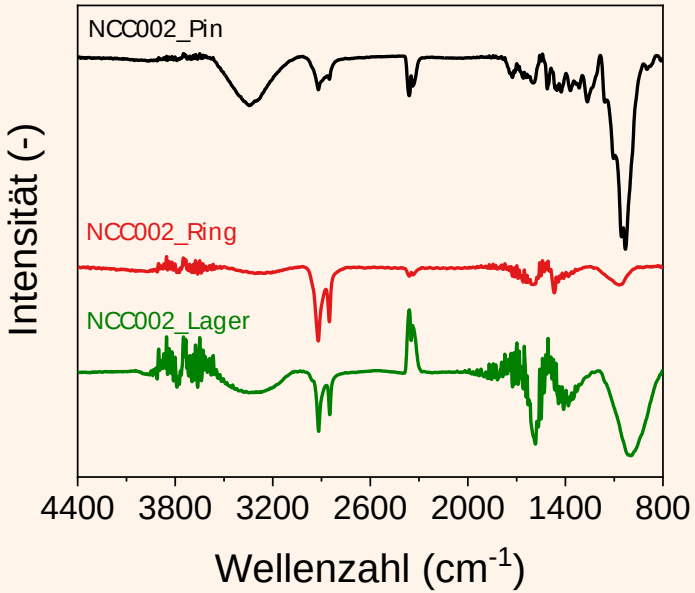
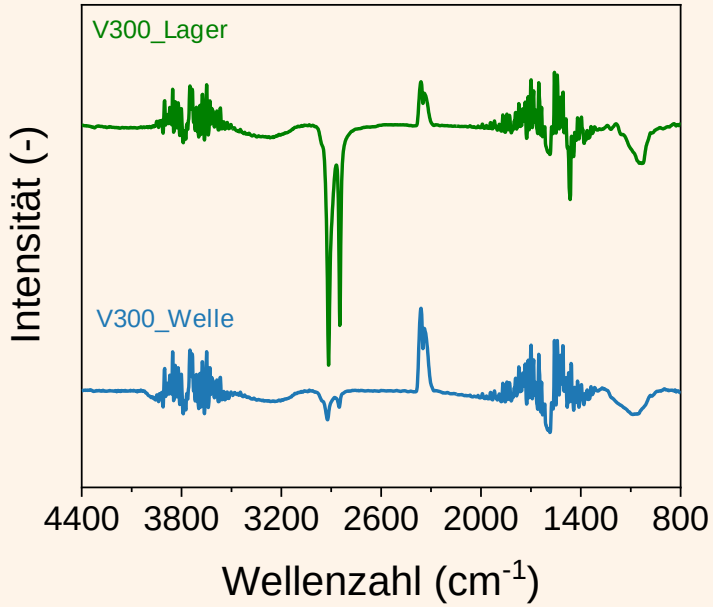
Results: FTIR Analyses





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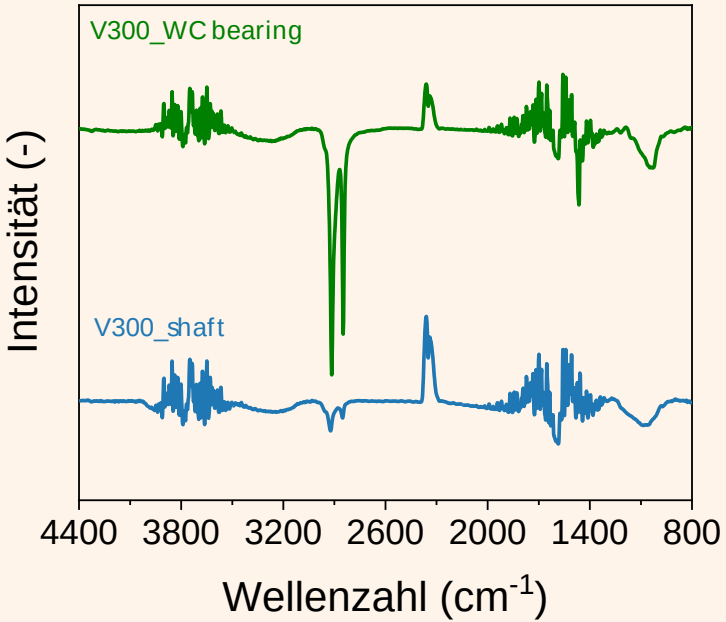
FTIR after bearing test shows less material transfer onto the shaft



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Conclusions

TRL5 reached.

- The specifications were suitable and a guideline for materials development and tribological assessment
- Very promising results are regarded a success:
    - Suitable mechanical material properties
    - Very low friction coefficients without the use of liquid lubricants
    - Acceptably low wear rates.
    - **All important materials specifications have been fulfilled.**
- Outlook: Finish the evaluation of the tribological performance of the WC materials on a model scale and prepare for component testing with real bearing geometries to demonstrate their feasibility for technical use.

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SWOT

S: Promising Materials, suitable mechanical properties, promising friction and wear behaviour.
S: Low PCF in synthesis and production, low energy consumption in use.
W: Concerns due scatter of material quality and low tensile strength
W: No experience in practical use
T: Validity of design rules unclear
T: Higher costs – can the be reduced to the same level as polymer bearings?
O: Representation of sustainability
O: Good chances on market once proof of concept will be shown for the whole product life cycle

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Roadmap

→ Upscale Production and Demonstration on TRL6

- Upscale production, including MW adaption
- Final retrofit and demonstration of feasibility of wood composite bearings
- Life of products and next use: Evaluation of recycling process and product quality

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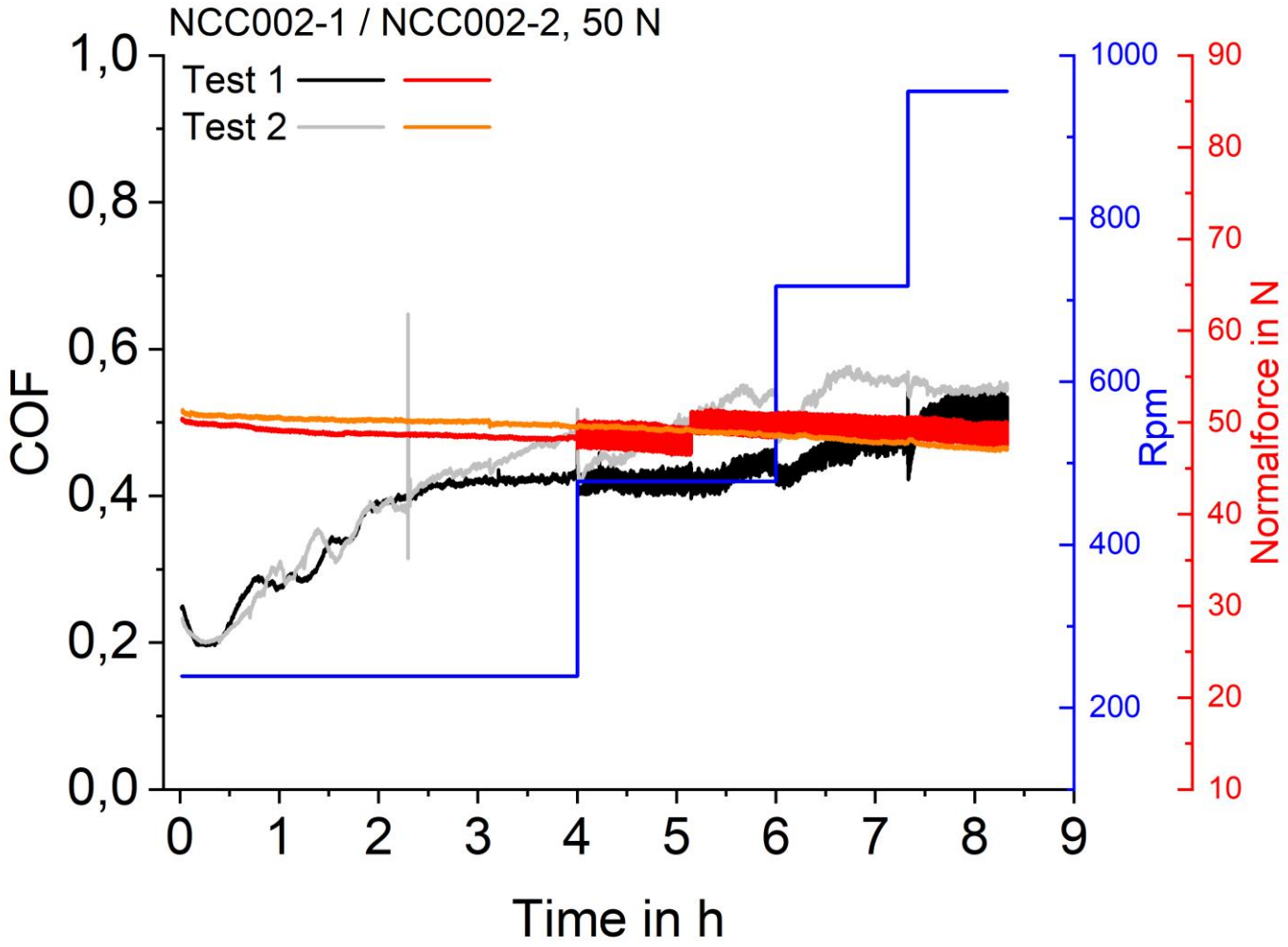
NCC002-1 / NCC002-2, 50 N
Test 1
Test 2
COF
1,0
0,8
0,6
0,4
0,2
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1
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8
9
Time in h
Rpm
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800
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400
200
Normalforce in N
90
80
70
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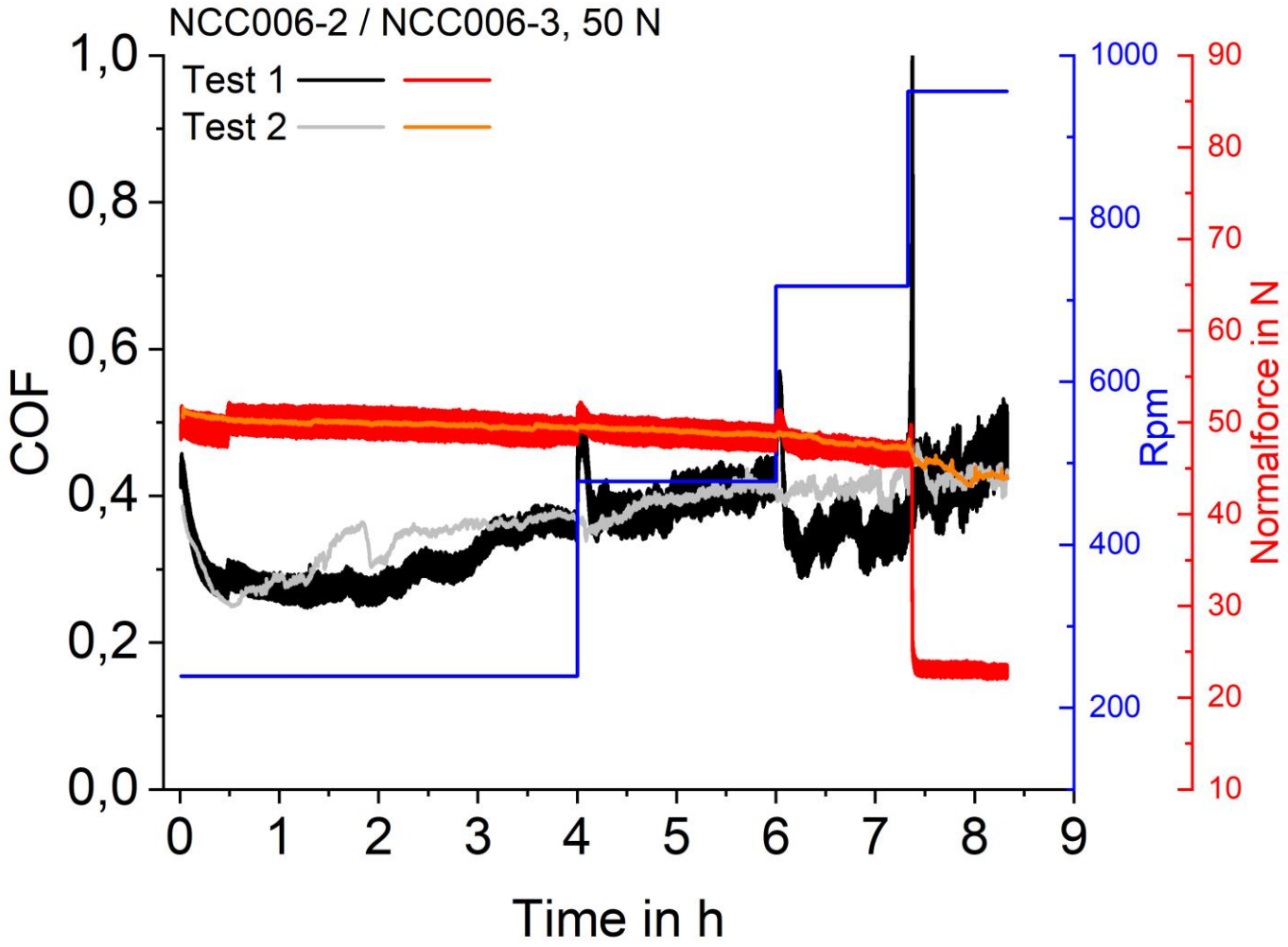
10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Test 1
Test 2
COF
Rpm
Normalforce in N
Time in h
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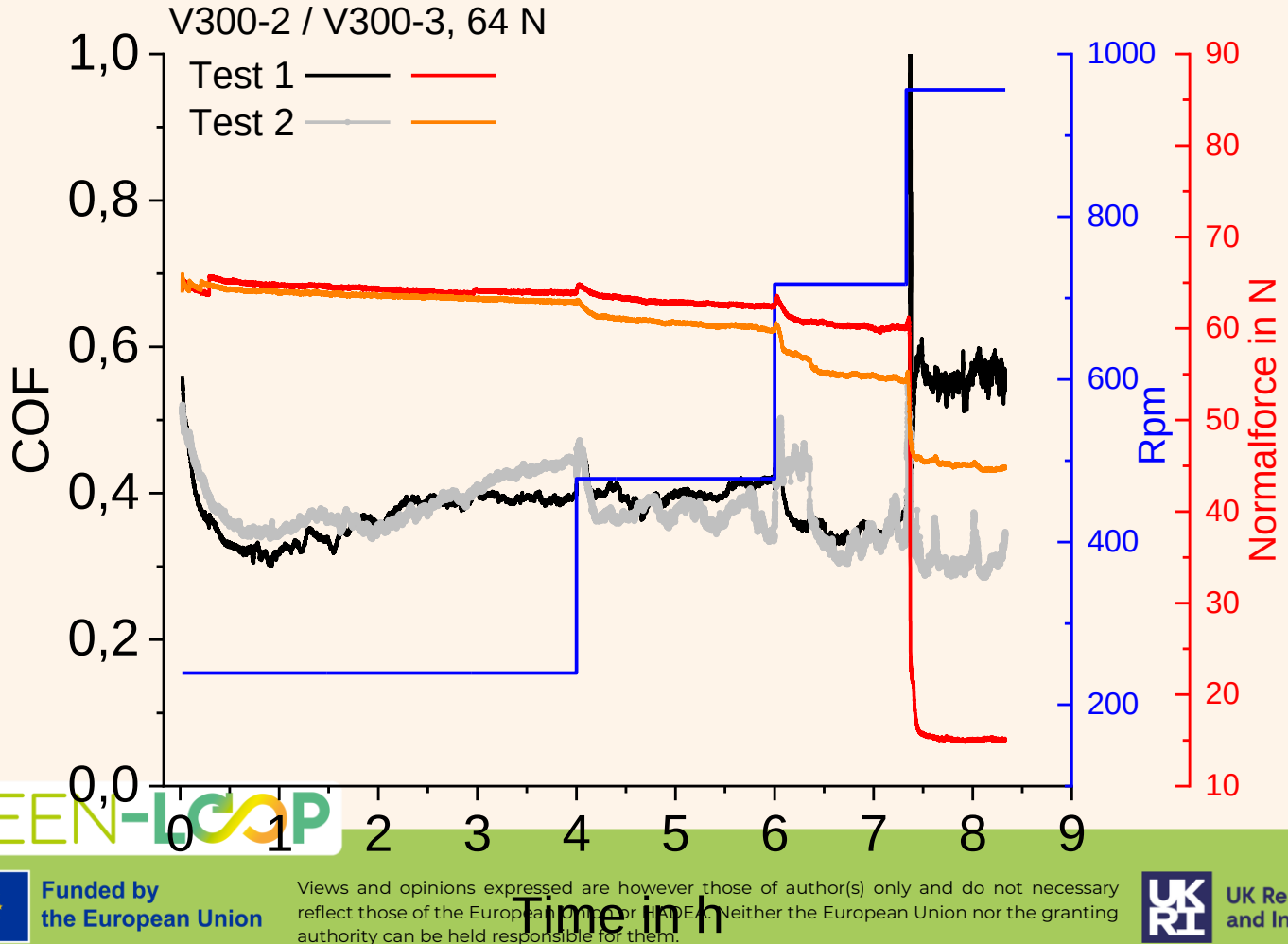

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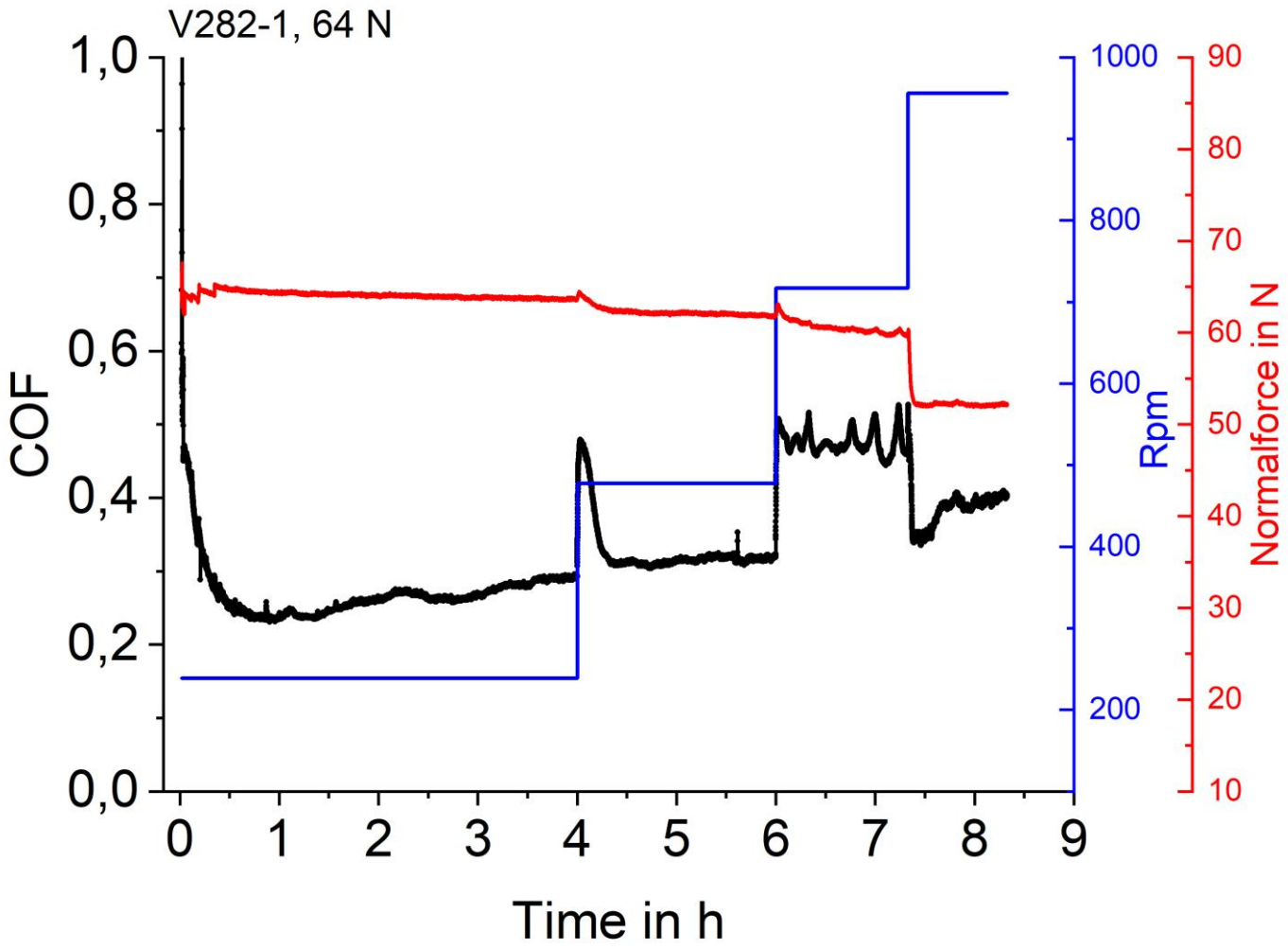
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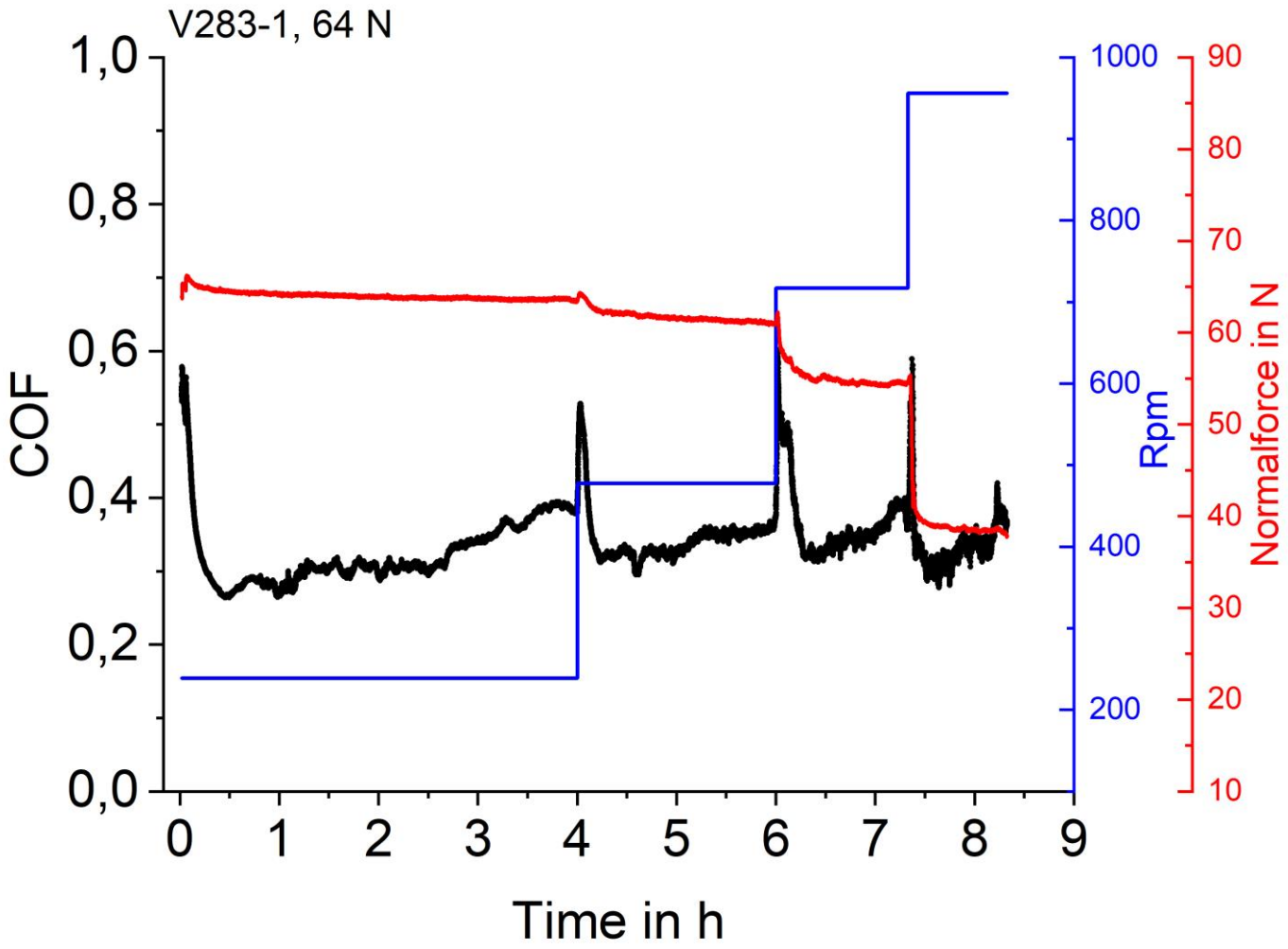
Time in h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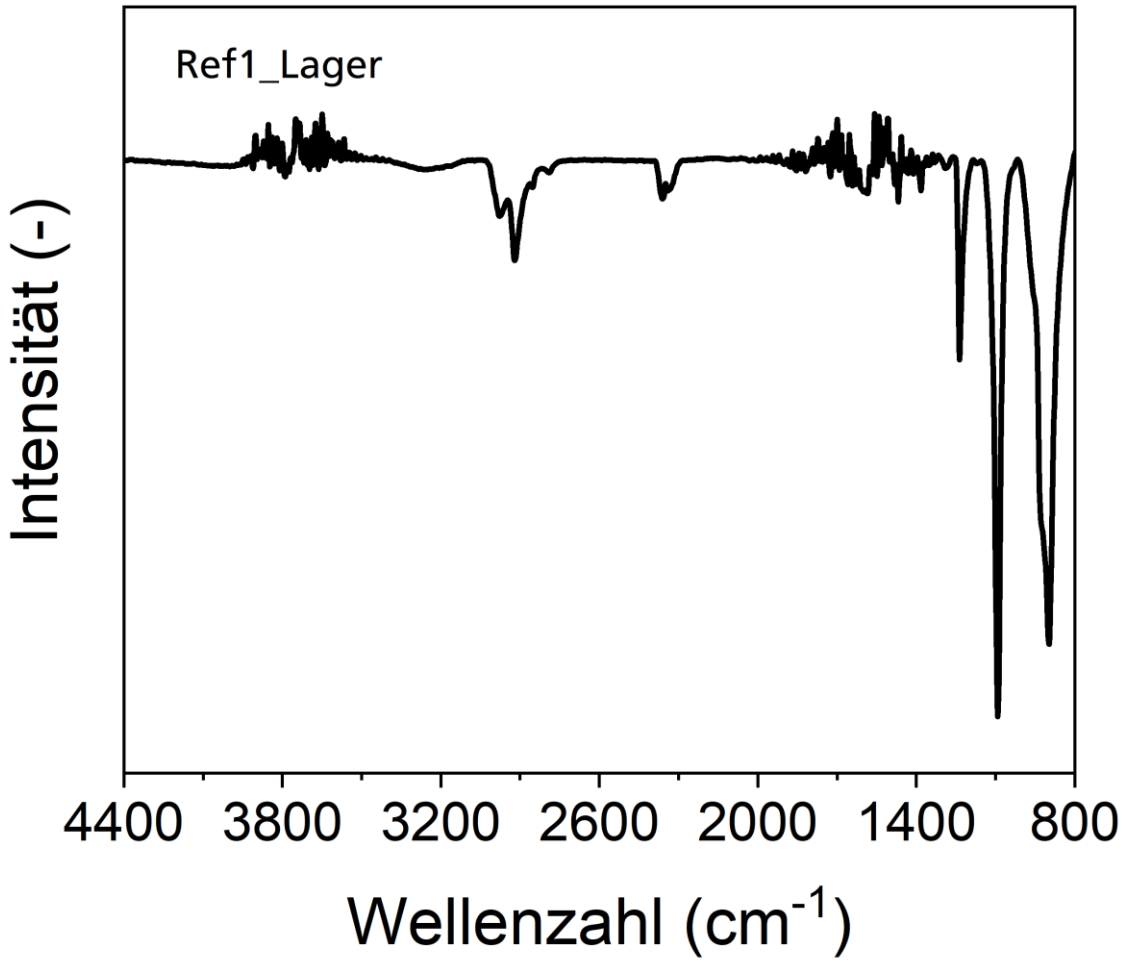
FTIR



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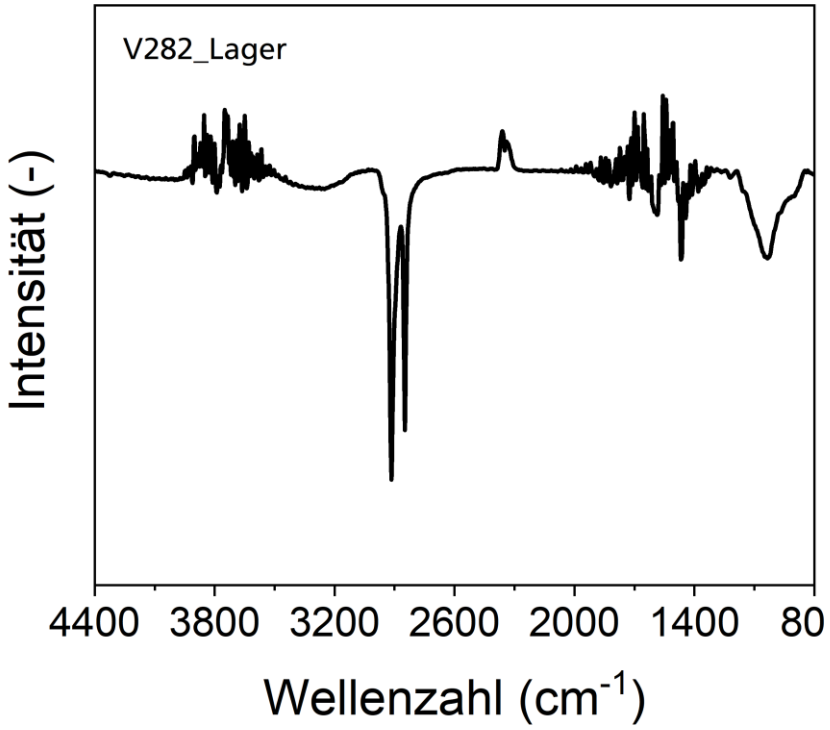

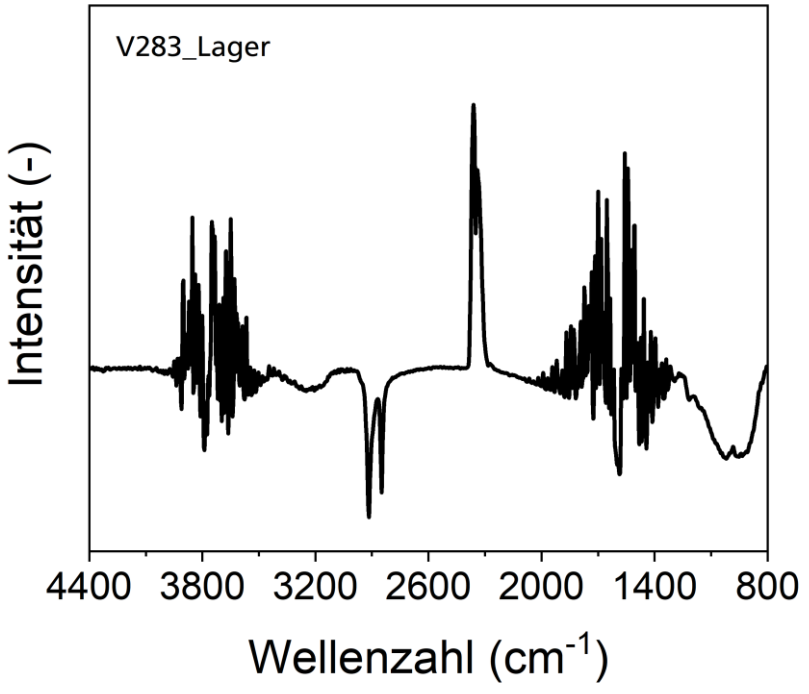

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WP5 – Deliverables status

Deliverable name	Due date	Deliverable Type	Status
D5.2 – Microwave design for WC extrusion	M20	Sen	submitted
D5.3 – WC sample manufacturing by press molding	M20	public	submitted
D5.4 – Sample quality and properties	M24	public	open
D5.5 – Tribology and tooling adaption	M24	public	submitted

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WP5 – Milestones status

Milestone name	Due date	Lead Beneficiary	Status
MS6 – Ultrasounds and microwave validation	M12	IDE	finished
MS7 – New tooling development	M14	IDE	finished
MS9 – Manufacture adaptation towards scaleup	M18	FHF	finished

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Open Issues and risks / Deviations from the DoA

Risk table WP5

No	Risk Category	Potential Risk	Possible Damage	Occurrence Probability		Consequence		Risk Level	Countermeasure	Resp.	Date for Re-Evaluation/ Comment	Status
1	Technical	**MW coupling** to selected formulations is not possible	No improvement of melting/ curing	Unlikely	3	Crisis	9	Moderate	Search for alternative susceptors, vary concentration, additives	IDE	**31.08.2024**	solved
2	Technical	**Enhancement through MW** too low	No reduction of energy consumption compared to electrical heating	Unlikely	3	Crises	9	Moderate	Optimization compound to improve MW coupling, power adaption	FHF/IDE	**30.09.2024**	solved

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Thanks for your attention!

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